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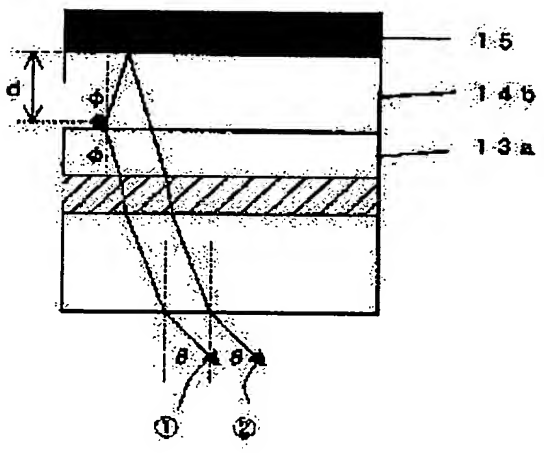
(54) ORGANIC ELECTROLUMINESCENCE ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To provide an organic electroluminescence(EL) element having high luminescence efficiency (light extraction efficiency), and low power consumption in high luminosity.

SOLUTION: The light, which is generated within the organic EL element, has two courses of the light (1), which directly goes ahead of the element, and the light (2), which goes ahead of the element after reflecting from a negative electrode 15. Since there is light pass difference, these light interfere mutually. The phase difference δ between the light, which comes out from a luminescence layer and goes directly ahead of the element, and the light, which reflected by the negative electrode, is obtained by $\delta=\pi+4\pi L/\lambda$ concerning to the normal direction of a substrate, in which λ is wavelength, and L is an optical distance from a light emitting position to a reflective face. The optical distance L is given by an optical film



thickness nd of an organic material which exists in from the luminescence position to the reflecting face (n is a refractive index and d is a film thickness). When the organic material, which exists from the luminescence position to the reflecting face, consists of a plurality of the layers, the optical distance L is given as the sum of the optical distance (optical film thickness) of each the organic layers.

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CLAIMS

[Claim(s)]
[Claim 1] The anode plate which consists of a transparent electrode, and the organic multilayers formed on said anode plate by having two-layer [of an electron hole transportation layer and an electronic transportation layer] at least, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.
[Claim 2] The anode plate which consists of a transparent electrode, and the organic multilayers formed by carrying out the laminating of two-layer in the order of an electron hole transportation layer and an electronic transportability luminous layer on said anode plate, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportability luminous layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.
[Claim 3] The anode plate which consists of a transparent electrode, and the organic multilayers formed by carrying out the laminating of the three layers on said anode plate in the order of a hole-injection layer, an electron hole transportation layer, and an electronic transportability luminous layer, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportability luminous layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.
[Claim 4] Said electronic transportability luminous layer is an organic electroluminescent element according to claim 2 or 3 characterized by doping the fluorescence ingredient of a minute amount near an interface with said electron hole transportation layer.
[Claim 5] The anode plate which consists of a transparent electrode, and the organic multilayers by which an electron hole transportation layer and thickness carried out the laminating of the three layers, and were formed on said anode plate in the order of a luminous layer 30nm or less and an electronic transportation layer, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.
[Claim 6] Said luminous layer is an organic electroluminescent element according to claim 5 characterized by doping the fluorescence ingredient of a minute amount.
[Claim 7] The anode plate which consists of a transparent electrode, and the organic multilayers formed

by carrying out the laminating of two-layer in the order of an electron hole transportability luminous layer and an electronic transportation layer on said anode plate, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.

[Claim 8] Said cathode is the organic electroluminescent element of the publication among [1 / any] claim 1 characterized by a reflection factor being 50% or more of metal membrane, claim 2, claim 3, claim 4, claim 5, claim 6, and claim 7.

[Claim 9] Said positive integer N is the organic electroluminescent element of the publication among [1 / any] claim 1 characterized by being 1, claim 2, claim 3, claim 4, claim 5, claim 6, claim 7, and claim 8.

[Claim 10] The optical thickness nd of said electronic transportation layer or said electronic transportability luminous layer is the organic electroluminescent element of the publication among [1 / any] claim 1 characterized by being among [error range] less than ** lambda/8 main wavelength of said luminescence; claim 2, claim 3, claim 4, claim 5, claim 6, claim 7, claim 8, and claim 9.

[Claim 11] Having the cathode produced by the anode plate which consists of a transparent electrode, the organic multilayers formed on said anode plate by having two-layer [of an electron hole transportation layer and an electronic transportation layer] at least, and the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers, the optical thickness nd of the electronic transportation layer of said organic multilayers is nd= (lambda/4) (2 N-delta r/pi). deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.

[Claim 12] Having the cathode produced by the anode plate which consists of a transparent electrode, the organic multilayers formed by carrying out the laminating of two-layer in the order of an electron hole transportation layer and an electronic transportability luminous layer on said anode plate, and the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers, the optical thickness nd of the electronic transportability luminous layer of said organic multilayers is nd= (lambda/4) (2 N-delta r/pi).
deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.

[Claim 13] Having the cathode produced by the anode plate which consists of a transparent electrode, the organic multilayers formed by carrying out the laminating of the three layers on said anode plate in the order of a hole-injection layer, an electron hole transportation layer, and an electronic transportability luminous layer, and the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers, the optical thickness nd of the electronic transportability luminous layer of said organic multilayers is nd= (lambda/4) (2 N-delta r/pi).
deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.

[Claim 14] Said electronic transportability luminous layer is an organic electroluminescent element according to claim 12 or 13 characterized by doping the fluorescence ingredient of a minute amount near an interface with said electron hole transportation layer.

[Claim 15] Having the cathode produced by the anode plate which consists of a transparent electrode, the organic multilayers by which an electron hole transportation layer and thickness carried out the laminating of the three layers, and were formed on said anode plate in the order of a luminous layer 30nm or less and an electronic transportation layer, and the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers, the optical thickness nd of the electronic transportation layer of said organic multilayers is nd= (lambda/4) (2 N-delta r/pi).

deltar=arctan(2nkr/(n2-(nr)2-(K[illegible])+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.

[Claim 16] Said luminous layer is an organic electroluminescent element according to claim 15 characterized by doping the fluorescence ingredient of a minute amount.

[Claim 17] Having the cathode produced by the anode plate which consists of a transparent electrode, the organic multilayers formed by carrying out the laminating of two-layer in the order of an electron hole transportability luminous layer and an electronic transportation layer on said anode plate, and the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers, the optical thickness nd of the electronic transportation layer of said organic multilayers is nd= (lambda/4) (2 N-delta r/pi).

deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- the organic electroluminescent element characterized by filling relation.

[Claim 18] Said cathode is the organic electroluminescent element of the publication among [1 / any] claim 11 characterized by a reflection factor being 50% or more of metal membrane, claim 12, claim 13, claim 14, claim 15, claim 16, and claim 17.

[Claim 19] Said positive integer N is the organic electroluminescent element of the publication among [1 / any] claim 11 characterized by being 1, claim 12, claim 13, claim 14, claim 15, claim 16, claim 17, and claim 18.

[Claim 20] The optical thickness nd of said electronic transportation layer or said electronic transportability luminous layer is the organic electroluminescent element of the publication among [1 / any] claim 11 characterized by being among [error range] less than ** lambda/8 main wavelength of said luminescence, claim 12, claim 13, claim 14, claim 15, claim 16, claim 17, claim 18, and claim 19.

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TECHNICAL FIELD

[Field of the Invention] This invention relates to an organic electroluminescent element (it considers as an organic EL device hereafter) with the high luminous efficiency which is the display of the flat-surface mold in which a multicolor display is possible, and a solid-state light emitting device available also as the light source.

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EFFECT OF THE INVENTION

[Effect of the Invention] invention according to claim 1 -- the optical thickness nd of the electronic transportation layer of organic multilayers -- nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be aimed at effectively. invention according to claim 2 -- the optical thickness nd of the electronic transportability luminous layer of organic multilayers -- nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily. invention according to claim 3 -- the optical thickness nd of the electronic transportability luminous layer of organic multilayers -- nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily. In invention according to claim 4, since the fluorescence ingredient of a minute amount is doped near the interface with an electron hole transportation layer, an electronic transportability luminous layer can make luminous efficiency high, can control by doping, the recombination field, i.e., the luminescence location, of a carrier, and can heighten further the cross protection by the optical thickness of an electronic transportation layer.
[0049] invention according to claim 5 -- the optical thickness nd of the electronic transportation layer of organic multilayers -- nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily. In invention according to claim 6, since the fluorescence ingredient of a minute amount is doped, a luminous layer can make luminous efficiency high, can control by doping, the recombination field, i.e., the luminescence location, of a carrier, and can heighten further the cross protection by the optical thickness of an electronic transportation layer. invention according to claim 7 -- the optical thickness nd of the electronic transportation layer of organic multilayers -- nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily.
[0050] In invention according to claim 8, since a reflection factor is 50% or more of metal membrane, cathode can take out cross protection effectively. Since positive integer N is 1, it will use the primary interference, and can make thickness of the organic film thin, and effectiveness is in a low-battery drive, and the thickness of the electronic transportation layer at this time can control it by invention according to claim 9 easily with the usual vacuum deposition as thinly as it has the influence of quenching by migration to the cathode of an exciton. In invention according to claim 10, since the optical thickness nd of an electronic transportation layer or an electronic transportability luminous layer is among [error range] less than ** lambda/8 main wavelength of luminescence, the enhancing effect of the luminescence reinforcement by cross protection is secured, bigger reinforcement than a convergence

value on the strength is obtained, and it can make easy quality control of a production process and a product by showing the tolerance of substantial thickness.

[0051] In invention according to claim 11, the optical thickness nd of the electronic transportation layer of organic multilayers nd= (lambda/4) (2 N-delta r/pi), deltar=arctan(2nkr/(n2-(nr)2-(Kr)2)) +pi, (It is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) Since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be aimed at effectively. In invention according to claim 12, the optical thickness nd of the electronic transportability luminous layer of organic multilayers nd= (lambda/4) (2 N-delta r/pi), deltar=arctan(2nkr/(n2-(nr)2-(Kr)2)) +pi, (It is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) Since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily. In invention according to claim 13, the optical thickness nd of the electronic transportability luminous layer of organic multilayers nd= (lambda/4) (2 N-delta r/pi), deltar=arctan(2nkr/(n2-(nr)2-(Kr)2)) +pi, (It is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) Since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily. In invention according to claim 14, since the fluorescence ingredient of a minute amount is doped near the interface with an electron hole transportation layer, an electronic transportability luminous layer can make luminous efficiency high, can control by doping, the recombination field, i.e., the luminescence location, of a carrier, and can heighten further the cross protection by the optical thickness of an electronic transportation layer.

[0052] In invention according to claim 15, the optical thickness nd of the electronic transportation layer of organic multilayers nd= (lambda/4) (2 N-delta r/pi), deltar=arctan(2nkr/(n2-(nr)2-(Kr)2)) +pi, (It is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) Since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily. In invention according to claim 16, since the fluorescence ingredient of a minute amount is doped, a luminous layer can make luminous efficiency high, can control by doping, the recombination field, i.e., the luminescence location, of a carrier, and can heighten further the cross protection by the optical thickness of an electronic transportation layer. In invention according to claim 17, the optical thickness nd of the electronic transportation layer of organic multilayers nd= (lambda/4) (2 N-delta r/pi), deltar=arctan(2nkr/(n2-(nr)2-(Kr)2)) +pi, (It is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) Since relation is filled, external ejection effectiveness of light can be made high and reduction of power consumption can be realized easily.

[0053] In invention according to claim 18, since a reflection factor is 50% or more of metal membrane, cathode can take out cross protection effectively. Since positive integer N is 1, by using the primary interference, it can make thickness of the organic film thin, and effectiveness is in a low-battery drive, and the thickness of the electronic transportation layer at this time can control it by invention according to claim 19 easily with the usual vacuum deposition as thinly as it has the influence of quenching by migration to the cathode of an exciton. In invention according to claim 20, since the optical thickness nd of an electronic transportation layer or an electronic transportability luminous layer is among [error range] less than ** lambda/8 main wavelength of luminescence, the enhancing effect of the luminescence reinforcement by cross protection is secured, bigger reinforcement than a convergence value on the strength is obtained, and it can make easy quality control of the production process by the tolerance of substantial thickness being shown, and a product.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] As a display device of a self-luminescence mold, the plasma display device and the organic EL device are known as mentioned above, for example. However, although a plasma display device uses plasma luminescence in low voltage gas and it is suitable for the large-sized display, it is unsuitable for thin-shape-izing and a miniaturization, and the technical problem in respect of cost remains. Moreover, for plasma luminescence, the high-voltage alternating current drive of several 100 V is needed, and it is not suitable for low-power-ization. Moreover, it originates in having not taken out effectively the light emitted from a luminous layer outside, even if it uses luminescent material with high internal quantum efficiency for an improvement of the luminous efficiency of an organic EL device, i.e., the ejection effectiveness of light being low, and there is a problem that luminous efficiency cannot be made high. Since total reflection of this will be carried out if the incident angle to the substrate side by the side of optical ejection mainly exceeds a critical angle, it originates in the ability of light not to be taken out from a substrate outside. For example, with the usual glass substrate, it is thought that it becomes about 25% of ejection effectiveness. Therefore, for the improvement in luminous efficiency of an organic EL device, to make light from a luminous layer the component configuration which can be effectively taken out to the component exterior is desired.
[0010] As one of the approaches of raising luminous efficiency (ejection effectiveness of luminescence) from the former, it is possible to use the reflected light from cathode effectively. That is, although it reflects ahead [component] (anode plate side) and the light emitted from the luminous layer can be effectively taken out if the metallic material which has a high reflection factor in a light field is used as a cathode material, it is possible that it interferes in the light which comes out of a luminous layer and goes directly ahead of a component, and the light reflected in cathode mutually, and it suits, and the present condition is that the exact and detailed examination about this cross protection is not made. Moreover, although it is shown in above-mentioned JP,4-137485,A that it is an important factor for the distance of a luminous layer and cathode to raise luminescence reinforcement, at this time, it is supposed that it is not fully solved about the reason for which luminescence reinforcement depends on the thickness of an electronic transportation layer. Moreover, the description about the relation between luminescence wavelength and thickness is not seen, and the examination about the cross protection of light is not made.
[0011] moreover, with the conventional technique of patent No. 3065704 and patent No. 3065705 Although it is said that it is set as the thickness within the limits which produce the brightness in which it has the thickness which contains the secondary maximal value of brightness high to the 2nd of a thickness brightness decay curve property for the thickness of EL layer or an electronic transportation layer, and the amplitude exceeds the convergence brightness value to converge The "formula 3" showing the luminous intensity as cross protection of the light indicated by patent No. 3065704 will be drawn without taking into consideration the phase change of pi radian of light reflected in cathode, and it will infringe Fresnel's law of reflection. That is, according to Fresnel's law of reflection, when light carries out incidence to the dense matter (matter with a big refractive index) from the **** matter (matter with a small refractive index) optically, it is known that, as for the phase of the reflected light,

only pi radian will change (for example, refer to the description about Lloyd's mirror of "interference and coherence" (Yoshiro Iinuma work, KYORITSU SHUPPAN), and coherence). Generally, the surface of metal where a reflection factor is high is the so-called mirror plane, and the phase of the reflected light carries out pi radian change mostly in a reflector. Thus, if the phase change of pi radian of the reflected light in cathode is disregarded, the thickness of EL layer which gives the maximal value of luminescence reinforcement may be set as that it cannot ask correctly and the thickness which serves as the minimal value of luminescence reinforcement conversely.

[0012] Although the surface of metal where a reflection factor is high is the so-called mirror plane and it is common to think that the phase of the reflected light carries out pi radian change mostly in a reflector, since, as for an actual metal, it has complex index of refraction, the substantial phase change of the reflected light in a reflector will shift from pi radian. Moreover, in the diffusion shell formed with the metal thin film, or a dielectric film with absorption, the substantial phase change of the reflected light in a reflector has shifted from pi radian similarly. Therefore, in choosing a busy cathode material, the substantial phase change of the reflected light in a reflector needed to be taken into consideration, but the present condition is that such [until now] examination is not made. Moreover, since high permeability is required of an anode plate in a light field since it is taken out from the field by the side of an anode plate by the component exterior, and the anode material of a big reflection factor cannot constitute EL luminescence from the patent No. 2846571 official report like cathode, strong cross protection is not expectable. Therefore, although it is effective in order for the configuration shown with this conventional technique to raise color purity, an extensive improvement of big luminous efficiency (ejection effectiveness of light) is not expectable. Similarly patent No. 2797883 does not specify the optical distance from the location of a luminous layer to cathode. Furthermore, the detailed explanation about the cross protection of light is not made, either.

[0013] Then, the purpose of this invention has high luminous efficiency (ejection effectiveness of light), and is offering the organic EL device of a low power by high brightness.

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MEANS

[Means for Solving the Problem] The organic multilayers formed in invention according to claim 1 on the anode plate which consists of a transparent electrode, and said anode plate by having two-layer [of an electron hole transportation layer and an electronic transportation layer] at least, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd= (2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. The organic multilayers formed by carrying out the laminating of two-layer in the order of an electron hole transportation layer and an electronic transportability luminous layer in invention according to claim 2 on the anode plate which consists of a transparent electrode, and said anode plate, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportability luminous layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. The organic multilayers formed by carrying out the laminating of the three layers in invention according to claim 3 on the anode plate which consists of a transparent electrode, and said anode plate in the order of a hole-injection layer, an electron hole transportation layer, and an electronic transportability luminous layer, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportability luminous layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. In invention according to claim 4, said electronic transportability luminous layer attains said purpose in invention according to claim 2 or 3 by doping the fluorescence ingredient of a minute amount near the interface with said electron hole transportation layer.
[0015] The organic multilayers by which an electron hole transportation layer and thickness carried out the laminating of the three layers, and were formed in invention according to claim 5 on the anode plate which consists of a transparent electrode, and said anode plate in the order of a luminous layer 30nm or less and an electronic transportation layer, It has the cathode produced by the specular reflection film which consists of a metal on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. In invention according to claim 6, said luminous layer attains said purpose by doping the fluorescence ingredient of a minute amount in invention according to claim 5.
[0016] The organic multilayers formed by carrying out the laminating of two-layer in the order of an electron hole transportability luminous layer and an electronic transportation layer in invention according to claim 7 on the anode plate which consists of a transparent electrode, and said anode plate, It has the cathode produced by the specular reflection film which consists of a metal on said organic many

membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd=(2N-1) lambda / 4 (for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. In invention according to claim 8, in invention of the publication among [1 / any] claim 1, claim 2, claim 3, claim 4, claim 5, claim 6, and claim 7, said cathode attains said purpose, when a reflection factor is 50% or more of metal membrane. In invention according to claim 9, said positive integer N attains said purpose by being 1 in invention of the publication among [1 / any] claim 1, claim 2, claim 3, claim 4, claim 5, claim 6, claim 7, and claim 8. In invention according to claim 10, the optical thickness nd of said electronic transportation layer or said electronic transportability luminous layer attains said purpose in invention of the publication among [1 / any] claim 1, claim 2, claim 3, claim 4, claim 5, claim 6, claim 7, claim 8, and claim 9 by being among [error range] less than ** lambda/8 main wavelength of said luminescence.

[0017] The organic multilayers formed in invention according to claim 11 on the anode plate which consists of a transparent electrode, and said anode plate by having two-layer [of an electron hole transportation layer and an electronic transportation layer] at least, It has the cathode produced by the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd= (lambda/4) (2N-delta r/pi) and deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. The organic multilayers formed by carrying out the laminating of two-layer in the order of an electron hole transportation layer and an electronic transportability luminous layer in invention according to claim 12 on the anode plate which consists of a transparent electrode, and said anode plate, It has the cathode produced by the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers. The optical thickness nd of the electronic transportability luminous layer of said organic multilayers nd= (lambda/4) (2N-delta r/pi) and deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. The organic multilayers formed by carrying out the laminating of the three layers in invention according to claim 13 on the anode plate which consists of a transparent electrode, and said anode plate in the order of a hole-injection layer, an electron hole transportation layer, and an electronic transportability luminous layer, It has the cathode produced by the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers. The optical thickness nd of the electronic transportability luminous layer of said organic multilayers nd= (lambda/4) (2N-delta r/pi) and deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. In invention according to claim 14, said electronic transportability luminous layer attains said purpose in invention according to claim 12 or 13 by doping the fluorescence ingredient of a minute amount near the interface with said electron hole transportation layer.

[0018] The organic multilayers by which an electron hole transportation layer and thickness carried out the laminating of the three layers, and were formed in invention according to claim 15 on the anode plate which consists of a transparent electrode, and said anode plate in the order of a luminous layer 30nm or less and an electronic transportation layer, It has the cathode produced by the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd= (lambda/4) (2N-delta r/pi) and deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. In invention according to claim 16, said luminous layer attains said purpose by doping the fluorescence ingredient of a minute amount in invention according to claim 15.

[0019] The organic multilayers formed by carrying out the laminating of two-layer in the order of an

electron hole transportability luminous layer and an electronic transportation layer in invention according to claim 17 on the anode plate which consists of a transparent electrode, and said anode plate, It has the cathode produced by the metal membrane which has complex-index-of-refraction n'=nr-ikr on said organic many membrane layers. The optical thickness nd of the electronic transportation layer of said organic multilayers nd= (lambda/4) (2N-delta r/pi) and deltar=arctan(2nkr/(n2-(nr)2-(Kr)2))+pi (it is n2 <=nr2+Kr2 and, for thickness and lambda, the main wavelength of luminescence and N are [n / a refractive index and d] a positive integer) -- said purpose is attained by filling relation. In invention according to claim 18, in invention of the publication among [1 / any] claim 11, claim 12, claim 13, claim 14, claim 15, claim 16, and claim 17, said cathode attains said purpose, when a reflection factor is 50% or more of metal membrane. In invention according to claim 19, said positive integer N attains said purpose by being 1 in invention of the publication among [1 / any] claim 11, claim 12, claim 13, claim 14, claim 15, claim 16, claim 17, and claim 18. In invention according to claim 20, the optical thickness nd of said electronic transportation layer or said electronic transportability luminous layer attains said purpose in invention of the publication among [1 / any] claim 11, claim 12, claim 13, claim 14, claim 15, claim 16, claim 17, claim 18, and claim 19 by being among [error range] less than ** lambda/8 main wavelength of said luminescence.

[0020]

[Embodiment of the Invention] Hereafter, the gestalt of suitable operation of this invention is explained to a detail with reference to drawing 1 thru/or drawing 12 . First, the organic EL device of the 1st operation gestalt is explained. The organic EL device of the gestalt of this operation is specular reflection film with which cathode consists of a metal, and is having the optical distance from a luminescence location to cathode set up so that the light which comes out of a luminous layer and goes directly ahead of a component, and the light reflected in cathode may suit in slight strength according to cross protection. Here, although the phase of the reflected light does not mean that only pi radian changes substantially that cathode is the specular reflection film to incident light by the interface with an organic layer and is not necessarily restricted to a metallic material, a reflection factor is high and the metallic material with high electron injection effectiveness is most suitable. Moreover, as it becomes the optimal component configuration to the main wavelength of an emission spectrum peculiar to luminescent material, the strongest light is effectively taken out to the component exterior.

[0021] Drawing 1 is drawing having shown interference of the light in an organic EL device. The light which emitted light within the organic EL device has two paths of optical ** which goes ahead of a component, after reflecting in optical ** and cathode 15 which go directly ahead of a component. Since such light has the optical path difference, it interferes in them mutually. The phase contrast delta of the light which comes out of a luminous layer and goes directly ahead of a component, and the light reflected in cathode is searched for by the following formulas (1) about the direction of a substrate normal.

Delta=pi +4pi L/lambda (1)

[0022] Here, lambda is wavelength and L is the optical distance from a luminescence location to a reflector. Optical distance L is given by the optical thickness nd of the organic material (for example, setting for the component of a two-layer mold electronic transportation layer) which exists even in a reflector from a luminescence location (n is a refractive index and d is thickness). When the organic material which exists even in a reflector from a luminescence location consists of two or more layers, optical distance L serves as the sum of the optical distance (optical thickness) of each organic layer. A luminescence location can be represented with the interface of electron hole transportation layer 13a/electronic transportability luminous layer 14b which shows the maximum luminescence reinforcement, or the interface location of a luminous layer (electron hole transportability) / electronic transportation layer. If it is extent which cannot disregard the luminescence intensity distribution in a luminous layer, it is also possible to correspond by adjusting thickness of an electronic transportation layer a little (more thickly [luminescence intensity distribution / one half extent]).

[0023] pi of the first term of the right-hand side of a formula (1) means the phase change of the reflected light in a reflector. The luminous intensity which comes out to the component exterior as cross

protection of direct light and the reflected light is proportional to D (lambda) given by the following formulas (2).
D(lambda) =1+cosdelta (2)
When the emission spectrum of the luminescent material itself is set to P (lambda), emission spectrum I (lambda) observed in the component exterior is expressed with a formula (3).
I(lambda) =P(lambda) D (lambda) (3)
Therefore, the luminous intensity as effectiveness of interference is max at the time of delta= 2Npi, and serves as min at the time of delta=(2N+1) pi (both N is positive integers). When this condition is rewritten using a formula (1), it is as follows.
Condition:L=(2N-1) lambda/4 from which reinforcement becomes max (4)
Condition:L=Nlambda/2 from which reinforcement becomes min (5)
[0024] The organic EL device of the gestalt of this operation is constituted so that the conditions of a formula (4) may be fulfilled. Moreover, if the amount of gaps from the optical distance L from which the maximum reinforcement given by the formula (4) is obtained is within the limits of ** lambda/8, bigger reinforcement at least than a convergence value (luminous-intensity value in case cross protection does not arise like [when thickness is thicker than coherence length]) on the strength will be obtained. Namely, what is necessary is just to fill the formula (4) within the limits of ** lambda/8 mostly at least in the gestalt of this operation, although a component is constituted so that a formula (4) may be satisfied completely. Moreover, since the optical distance from which luminescence reinforcement becomes max, and its range which can be set up change with wavelength, it is set up according to the emission spectrum of various luminescent material.
[0025] Moreover, the configuration of the organic EL device of the gestalt of this operation is applicable in all in case the interface location which shows the component of the two-layer mold currently indicated with the conventional technique as shown by drawing 13 or drawing 14 , or a three-layer mold, and the maximum luminescence reinforcement of a luminous layer is known. Moreover, based on the doped location, when doping a fluorescence ingredient to a luminous layer, the optical distance L to cathode is set up so that a formula (4) may be filled. If the case where positive integer N showing order of interference is 1 is adopted, since thickness of the organic film (electronic transportation layer) can be made thin, it is effective in a low-battery drive. The refractive index n of the organic material used for an organic EL device is 1.6 to about 1.8. For example, if it is the refractive index n= 1.7 of an organic material in the component of a two-layer mold, the thickness with the optimal electronic transportation layer will be set to 75nm to the main wavelength of lambda= 510nm of luminescence of Almq3 which is the luminescent material known well. With vacuum deposition, this thickness is fully stabilized, and can be produced, and the effect of quenching by migration to the cathode of an exciton is not produced. The photoluminescence spectrum P of Almq3 which used and measured the spectrophotofluorometer to drawing 2 as an example of an emission spectrum peculiar to luminescent material (lambda) is shown.
[0026] The emission spectrum which the distance (thickness of an electronic transportation layer) from a luminescence location to cathode calculated [film / of a refractive index n= 1.7 / organic] about the case of **38nm, **75nm, **112nm, and **150nm is shown in drawing 3 using the photoluminescence spectrum P (lambda) shown in drawing 2 , a formula (1), a formula (2), and a formula (3). As for luminescence reinforcement, it turns out that thickness is max and the value of almost the middle in min, 38nm, and 112nm 150nm in 75nm. Moreover, the brightness value which calculated the CIE color system as although it was made JIS-Z 8701-1982, and was calculated is shown in drawing 4 based on the spectrum which calculated it by having changed thickness little by little. It turns out that the max and min of brightness are clearly reversed by thickness in 400nm or less.
[0027] Next, although the production approach of the organic EL device concerning the gestalt of this operation is explained, a well-known approach can be used fundamentally. First, transparent electrodes, such as ITO, are formed by about 10-300nm thickness by vacuum deposition or sputtering on a glass substrate, and let this be an anode plate. What is marketed as a glass substrate with ITO is easily available. On ITO, sequential formation of the organic materials, such as an electron hole transportation layer, a luminous layer, and an electronic transportation layer, is carried out so that it may become

predetermined thickness with vacuum evaporation technique, a spin coating method, etc. In the component of a two-layer mold, an electron hole transportation layer or an electronic transportation layer will serve as a luminous layer.

[0028] As the ingredient which forms the luminous layer and electron hole transportation layer which are used in the organic EL device of the gestalt of this operation, and an electronic transportation layer was shown in drawing 5 , as an ingredient of electron hole transportability, a triphenyl diamine derivative (TPD), a triphenylamine derivative (NSD), alpha-naphthyl FENIJIRU amine (alpha-NPD), phthalocyanines (CuPc, H2Pc), and starburst polyamine (m-MTDATA) are used. As an electronic transportation ingredient, an aluminum quinolinol complex (Alq3), a methyl aluminum quinolinol complex (4-Methyl-8-hydroxyquinoline:Almq3), a beryllium quinoline complex (Beq2), etc. can be used, and these ingredients are used for coincidence also as a luminescent ingredient. The OKISA diazole derivative (PBD) is well known as an outstanding electronic transportation ingredient. If the good ingredient of electronic transportability like PBD is used as an electronic transportation layer, the component of the three-tiered structure which separated the luminous layer and the carrier transportation layer, or the two-layer structure of having an electron hole transportability luminous layer is realizable.

[0029] Furthermore, a coumarin derivative, Quinacridone, rubrene, etc. can be used as a doping ingredient. the vapor codeposition using two heating boats for example as the approach of doping -- luminescent material, such as Alq3, -- a host ingredient -- carrying out -- an interface (less than about 30nm) near [with an electron hole transportation layer] -- a fluorescence ingredient -- % - the number of several mols -- about 10mol% -- it can dope. next, the vacuum deposition according [cathode] a metallic material to resistance heating, an electron beam, etc. -- or it is formed by about 10-300nm thickness using the sputtering method using an alloy target etc. In order to obtain sufficient reflection factor and the film of low resistance, it is desirable to make it preferably thickness 100nm or more. As a metallic material used for cathode, metallic element simple substances or these alloys, such as a metal with a small work function, for example, Li (lithium), Na (sodium), Mg (magnesium), calcium (calcium), Sr (strontium), aluminum (aluminum), Ag (silver), In (indium), Sn (tin), Zn (zinc), Zr (zirconium), etc., are used. Furthermore, LiF etc. may be formed by the same approach as the case of cathode as an electrode protective coat on cathode. In addition, with the gestalt of this operation, as long as the cathode which consists of a metal membrane which has the specular reflection interface which carries out the phase change only of pi substantially is used, luminous efficiency is improvable by not being based on the difference in the laminating configuration of a component, but setting up the optical distance from the location of a luminous layer to cathode based on this invention. Furthermore, it is possible not only an organic EL device but to apply the fundamental view of the gestalt of this operation in the similar field light emitting device using specular reflection.

[0030] Hereafter, although the 1st modification 1 and modification 2 of an operation gestalt are explained, the organic EL device concerning the gestalt of this operation is not limited only to the ingredient in these operation gestalten, and a component configuration.

(1) Modification 1 board thickness prepares the glass substrate with ITO which is 1.1mm, and forms the electrode pattern of 2mm width of face by the photolithography method using a general resist. Next, wash this substrate using a surfactant, after fully flushing a detergent with pure water, it is made to dry in the steam of isopropyl alcohol, and the dirt of surface washing is fully further removed by oxygen plasma treatment. Thus, the prepared substrate is set in a vacuum evaporation system, vacuum deposition of alpha-NPD is carried out by resistance heating as an electron hole transportation ingredient, and the electron hole transportation layer whose thickness is 70nm is formed. 2.7x10 to 4 Pa and a vacuum evaporationo rate carry out vacuum evaporationo conditions in 1nm/second, and further, continuously, a degree of vacuum vapor-deposits Almq3 similarly, and makes them a 75nm electronic transportability luminous layer.

[0031] Next, in the condition of having stuck to the substrate the metal mask with which a hole which intersects perpendicularly by the ITO electrode pattern and 2mm width of face was made, and having set in the vacuum evaporation system, vacuum deposition of the aluminum (aluminum) is carried out, and the metal membrane of 160nm of thickness is formed, it considers as cathode, and the lighting field of

2mm angle is obtained. On aluminum electrode, LiF whose thickness is 300nm is vapor-deposited, a protective coat is formed, in an inert gas (Ar) ambient atmosphere, the Pyrex (trademark) glass of 1mm thickness is piled up on this component, the glass circumference is closed using the adhesives of an ultraviolet curing mold, and an organic EL device is obtained. The location which shows the maximum luminescence reinforcement is alpha-NPD and near the interface of Almq3, and the optical distance to cathode satisfies the relational expression given by nd=(2N-1) lambda/4. In addition, for n, a refractive index and d are [the main wavelength of luminescence and N of thickness and lambda] positive integers.

[0032] (2) As a modification 2 hole-injection layer, form m-MTDATA by 30nm thickness on an ITO electrode, continuously, as an electron hole transportation layer, form alpha-NPD by 50nm thickness, and form the electronic transportability luminous layer which consists of Almq3 further by 75nm thickness. Other configurations produce an organic EL device like a modification 1.

[0033] Next, the organic EL device of the 2nd operation gestalt is explained. In the organic EL device of this operation gestalt, cathode is the metallic reflection film like the 1st operation gestalt, and the optical distance from a luminescence location to cathode is set up so that the light which comes out of a luminous layer and goes directly ahead of a component, and the light reflected in cathode may suit in slight strength according to cross protection. Although cathode does not have light reflex ability, is not made in consideration of the substantial phase change of the reflected light in a reflector and is not necessarily restricted to a metallic material, a reflection factor is high and the metallic material with high electron injection effectiveness is most suitable. Moreover, as it becomes the optimal component configuration to the main wavelength of an emission spectrum peculiar to luminescent material, the strongest light is effectively taken out to the component exterior.

[0034] The light which emitted light within the organic EL device has two paths of optical ** which goes ahead of a component, after reflecting in optical ** and cathode which go directly ahead of a component (refer to drawing 1). Since such light has the optical path difference, it interferes in them mutually. The phase contrast delta of the light which comes out of a luminous layer and goes directly ahead of a component, and the light reflected in cathode expresses the phase change of the reflected light in a reflector as deltar, and is given by the following formulas (6) about the direction of a substrate normal.

Delta=delta r+4pi L/lambda (6)

In addition, lambda is wavelength and L is the optical distance from a luminescence location to a reflector. Optical distance L is given by the optical thickness nd of the organic material (for example, setting for the component of a two-layer mold electronic transportation layer) which exists even in a reflector from a luminescence location (n is a refractive index and d is thickness). When the organic material which exists even in a reflector from a luminescence location consists of two or more layers, optical distance L serves as the sum of the optical distance (optical thickness) of each organic layer. A luminescence location can be represented with the interface of the electron hole transportation layer / luminous layer (electronic transportability) which shows the maximum luminescence reinforcement, or the interface location of a luminous layer (electron hole transportability) / electronic transportation layer. If it is extent which cannot disregard the luminescence intensity distribution in a luminous layer, it is also possible to correspond by adjusting thickness of an electronic transportation layer a little (more thickly [luminescence intensity distribution / one half extent]).

[0035] Here, if the refractive index of the transparent organic material which touches n'=nr-ikr (nr and kr are called an optical constant) and cathode in the complex index of refraction of a cathode material is expressed as n, if it asks for phase change deltar of the reflected light in a reflector using the formula of reflection of Fresnel, it can be expressed with a formula like drawing 6 (a). Moreover, the luminous energy reflection factor R in a reflector can be expressed with the formula of drawing 6 (b). a metaled optical constant is measured by reflection factor measurement, the ellipsometry method, etc. (in addition -- the optical constant of a metallic element -- work besides "thin film" Kinbara, Shokabo Publishing, 209 pages, and the Junpei work in the "optical introduction I" crossing, Asakura Publishing, and 50 pages (American Institute of Physics Handbook (McGraw-Hill, 1972, p6 -118 reference).)) The

luminous intensity which comes out to the component exterior as cross protection of direct light and the reflected light is proportional to D (lambda) given by drawing 6 (c).
[0036] When the emission spectrum of the luminescent material itself is set to P (lambda), emission spectrum I (lambda) observed in the component exterior is expressed with drawing 6 (d). Therefore, the luminous intensity as effectiveness of interference is max at the time of delta= 2Npi, and serves as min at the time of delta=(2N+1) pi (both N is a positive integer). If this condition is rewritten using a formula (1), it will become like drawing 7 . The organic EL device of the gestalt of this operation constitutes a component so that the conditions of the formula of drawing 7 (a) may be fulfilled. Moreover, if the amount of gaps from the optical distance L from which the maximum reinforcement given by drawing 7 (a) is obtained is within the limits of ** lambda/8, bigger reinforcement at least than a convergence value (luminous-intensity value in case cross protection does not arise like [when thickness is thicker than coherence length]) on the strength will be obtained. Namely, what is necessary is just to fill within the limits of ** lambda/8 at least in the gestalt of this operation, although a component is constituted so that drawing 7 (a) may be satisfied completely. Moreover, since the optical distance from which luminescence reinforcement becomes max, and its range which can be set up change with wavelength, it is set up according to the emission spectrum of various luminescent material.
[0037] Moreover, the configuration of the organic EL device of the gestalt of this operation is applicable in all in case the interface location which shows the component of the two-layer mold of the conventional technique or a three-layer mold and the maximum luminescence reinforcement of a luminous layer is known. Moreover, based on the doped location, when doping a fluorescence ingredient to a luminous layer, the optical distance L to cathode is set up so that the formula of drawing 7 (a) may be filled. If the case where positive integer N showing order of interference is 1 is adopted, since thickness of the organic film (electronic transportation layer) can be made thin, it is effective in a low-battery drive. The refractive index n of the organic material used for an organic EL device is 1.6 to about 1.8.
[0038] It will be set to deltar=2.195[radian] and R= 0.973 if it asks for the phase change and reflection factor in an interface from drawing 6 (a) and (b) about optical constant nr=0.055 of the vacuum evaporationo film of Ag, and kr=3.32 as an example, using as n= 1.7 the refractive index of the organic material (electronic transportation layer) which touches Ag. The thickness with the optimal electronic transportation layer for which it asked from drawing 7 (a) based on this value from the main wavelength of lambda= 510nm of luminescence of Almq3 which is luminescent material (it serves as an electronic transportation layer) is set to 98nm. Since it is 75nm when it calculates as a delta r=pi radian, only 23nm is understood that thickness is thick. With vacuum deposition, this thickness is fully stabilized, and can be produced, and the effect of quenching by migration to the cathode of an exciton is not produced.
[0039] The photoluminescence spectrum P of Almq3 (lambda) measured using a spectrophotofluorometer as an example of an emission spectrum peculiar to luminescent material is shown in drawing 2 like the 1st operation gestalt. The main wavelength of luminescence is seen by lambda= 510nm. The emission spectrum which the distance (thickness of an electronic transportation layer) from a luminescence location to cathode calculated [film / of a refractive index n= 1.7 / organic] about the case of **61nm, **98nm, **135nm, and **173nm is shown in drawing 8 using the photoluminescence spectrum P (lambda) shown in drawing 2 , drawing 6 (c), and (d). As for luminescence reinforcement, thickness serves as max by 98nm (it corresponds to N= 1), and the emission spectrum of ingredient original is reproduced. It turns out that thickness is the value of almost the middle [reinforcement / luminescence] in min, 61nm, and 135nm in 173nm.
[0040] Hereafter, the production approach of the organic EL device of the 2nd operation gestalt is explained. In addition, the production approach of an organic EL device can use a well-known approach fundamentally. First, transparent electrodes, such as ITO, are formed by about 10-300nm thickness by vacuum deposition or sputtering on a glass substrate, and let this be an anode plate. Or what is marketed as a glass substrate with ITO is easily available. On ITO, sequential formation of the organic materials, such as an electron hole transportation layer, a luminous layer, and an electronic transportation layer, is carried out so that it may become predetermined thickness with vacuum evaporation technique, a spin

coating method, etc. In the component of a two-layer mold, an electron hole transportation layer or an electronic transportation layer will serve as a luminous layer.

[0041] The conventional thing can be used for the ingredient which forms the luminous layer and electron hole transportation layer which are used in the organic EL device of the gestalt of this operation, and an electronic transportation layer. As an ingredient of for example, electron hole transportability as shown in drawing 5 , a triphenyl diamine derivative (TPD), a triphenylamine derivative (NSD), alpha-naphthyl FENIJIRU amine (alpha-NPD), phthalocyanines (CuPc, H2Pc), and starburst polyamine (m-MTDATA) are used. As an electronic transportation ingredient, there are an aluminum quinolinol complex (Alq3), a methyl aluminum quinolinol complex (4-Methyl-8-hydroxyquinoline:Almq3), a beryllium quinoline complex (Beq2), etc., and these ingredients are used for coincidence also as a luminescent ingredient. The OKISA diazole derivative (PBD) is well known as an outstanding electronic transportation ingredient. If the good ingredient of electronic transportability like PBD is used as an electronic transportation layer, the component of the three-tiered structure which separated the luminous layer and the carrier transportation layer, or the two-layer structure of having an electron hole transportability luminous layer is realizable.

[0042] Furthermore, a coumarin derivative, Quinacridone, rubrene, etc. can be used as a doping ingredient. the vapor codeposition using two heating boats for example as the approach of doping -- luminescent material, such as Alq3, -- a host ingredient -- carrying out -- an interface (less than about 30nm) near [with an electron hole transportation layer] -- a fluorescence ingredient -- % - the number of several mols -- about 10mol% -- it can dope. next, the vacuum deposition according [cathode] a metallic material to resistance heating, an electron beam, etc. -- or it is formed by about 10-300nm thickness using the sputtering method using an alloy target etc. In order to obtain sufficient reflection factor and the film of low resistance, it is desirable to make it preferably thickness 100nm or more. As a metallic material used for cathode, metallic element simple substances or these alloys, such as a metal with a small work function, for example, Li, Na, Mg, calcium, Sr, Ba, Ti, Mn, aluminum, Ag, In, Sn, Zn, Zr, etc., are used. Alkaline metals are used as an alloy with Ag, aluminum, etc., in order to improve adhesion with the organic film and to avoid degradation by oxygen, moisture, etc. Furthermore, LiF and SiO2 grade may be formed by the same approach as the case of cathode as an electrode protective coat on cathode.

[0043] The phase change and reflection factor in the optical constant and reflector of various metallic elements are shown in drawing 9 . The refractive index of the organic material which touches a metal side is set to n= 1.7. ** et al. -- ** -- all metals have deltar within the limits of pi/2 - pi. When these metallic elements are used for cathode and an organic EL device is formed, the result to which order of interference calculated thickness with the optimal electronic transportation layer by the case of N= 1, and 2 and 3 from the formula of drawing 6 (a) is shown in drawing 10 . The wavelength dispersion of optical constants, such as metals other than these and other alloys, or an optical constant is measurable by the ellipsometry method etc.

[0044] Hereafter, although the modifications 1-3 of the 2nd operation gestalt are explained, the modification of the 2nd operation gestalt is not limited only to these ingredients and a component configuration.

(1) Use aluminum (aluminum) as a metallic material which forms modification 1 cathode. Board thickness prepares the glass substrate with ITO which is 1.1mm, and forms the electrode pattern of 2mm width of face by the photolithography method using a general resist. Next, wash this substrate using a surfactant, after fully flushing a detergent with pure water, it is made to dry in the steam of isopropyl alcohol, and the dirt of surface washing is fully further removed by oxygen plasma treatment. Thus, the prepared substrate is set in a vacuum evaporation system, vacuum deposition of alpha-NPD is carried out by resistance heating as an electron hole transportation ingredient, and the electron hole transportation layer whose thickness is 70nm is formed.

[0045] 2.7x10 to 4 Pa and a vacuum evaporationo rate carry out [a degree of vacuum] vacuum evaporationo conditions in 1nm/second. Furthermore, continuously, Almq3 was vapor-deposited similarly and it considered as the electronic transportability luminous layer. The thickness of Almq3 is

set up so that it may be mostly in agreement with the optimal thickness value of 87nm calculated as N= 1 by the formula (1). That is, the location which shows the maximum luminescence reinforcement is alpha-NPD and near the interface of Almq3, and the optical distance to cathode will have satisfied relational expression like drawing 11 . Next, in the condition of having stuck to the substrate the metal mask with which a hole which intersects perpendicularly by the ITO electrode pattern and 2mm width of face was made, and having set in the vacuum evaporation system, vacuum deposition of the aluminum (aluminum) is carried out, and the metal membrane of 160nm of thickness is formed, it considers as cathode, and the lighting field of 2mm angle is obtained. On aluminum electrode, thickness vapor-deposits LiF which is 300nm, and forms a protective coat. Furthermore, in an inert gas (Ar) ambient atmosphere, the Pyrex glass of 1mm thickness is piled up on this component, the glass circumference is closed using the adhesives of an ultraviolet curing mold, and an organic EL device is obtained.

[0046] (2) As a modification 2 hole-injection layer, form m-MTDATA by 30nm thickness on an ITO electrode, continuously, as an electron hole transportation layer, form alpha-NPD by 50nm thickness, and form the electronic transportability luminous layer which consists of Almq3 still like a modification 1 by 87nm thickness. Other configurations produce an organic EL device like a modification 1.

[0047] (3) Constitute an organic EL device using the same organic material as a modification 2 except having used the MgAg alloy whose thickness is 150nm as a metallic material which forms modification 3 cathode. The vapor codeposition which used Mg and Ag performs film production of cathode. The optical constants of a MgAg alloy were nr=0.3 and kr=5, as a result of measuring by the ellipsometry method using the sample which produced the film on the glass substrate on the same conditions as the case where a component is formed. The phase change of the reflected light in the reflector searched for from the formula of drawing 12 is set to deltar=2.5 (radian) using this optical constant. The thickness of an electronic transportation layer produces a film so that it may become the thickness value of 91nm calculated as N= 1 from a formula like drawing 11 .

[Translation done.]

* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing having shown interference of the light in an organic EL device.
[Drawing 2] It is drawing having shown the photoluminescence spectrum of Almq3.
[Drawing 3] It is drawing having shown the difference in the emission spectrum at the time of changing the thickness of the electronic transportation layer in the 1st operation gestalt.
[Drawing 4] It is drawing having shown the thickness of an electronic transportation layer, and the relation of a brightness value.
[Drawing 5] It is drawing having shown the structure expression of an electronic transportability ingredient and an electron hole transportability ingredient.
[Drawing 6] It is drawing having shown phase change deltar, reflection-coefficient-of-sound-energy-intensity R, luminous intensity, and the formula that asks for emission spectrum I (lambda).
[Drawing 7] It is drawing having shown the formula which finds the optical distance from the luminescence location according to conditions on the strength to a reflector.
[Drawing 8] It is drawing having shown the difference in the emission spectrum at the time of changing the thickness of the electronic transportation layer in the 2nd operation gestalt.
[Drawing 9] It is drawing having shown the phase change and reflection factor in the optical constant and reflector of various metallic elements.
[Drawing 10] It is drawing having shown the optimal thickness of the electronic transportation layer at the time of using as cathode the various metals with which optical constants differ.
[Drawing 11] It is drawing having shown the setups (1) of the optical thickness of the electronic transportation layer of an organic EL device.
[Drawing 12] It is drawing having shown the setups (2) of the optical thickness of the electronic transportation layer of an organic EL device.
[Drawing 13] It is the outline sectional view showing the lamination of the organic EL device of a two-layer mold which has an electronic transportability luminous layer.
[Drawing 14] It is the outline sectional view showing the lamination of the organic EL device of a two-layer mold which has an electron hole transportability luminous layer.
[Description of Notations]
1 Glass Substrate
2 Anode Plate (Transparent Electrode)
3a, 13a Electron hole transportation layer
3b Electron hole transportability luminous layer
4a Electronic transportation layer
4b, 14b Electronic transportability luminous layer
5 15 Cathode (metal electrode)
6 Luminescence Location

[Translation done.]

* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

[Drawing 7]

(a)
強度が最大になる条件： $L=\frac{\lambda}{4}\left(2N-\frac{\delta r}{\pi}\right)$

(b)
強度が最小になる条件： $L=\frac{\lambda}{4}\left(2N+1-\frac{\delta r}{\pi}\right)$

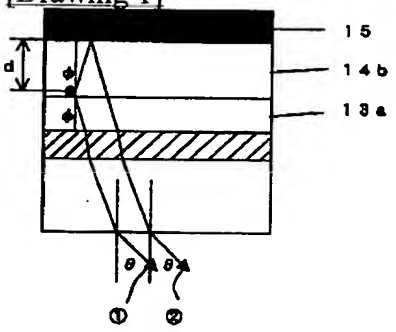
[Drawing 11]

$nd=\frac{\lambda}{4}\left(2N-\frac{\delta r}{\pi}\right)$

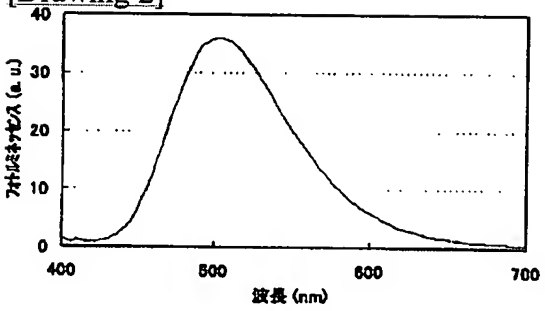
[Drawing 12]

$\delta r=\arctan\left(\frac{2nk_r}{n^2-n_r^2-k_r^2}\right)+\pi$ （ただし、$n^2 \leq n_r^2+k_r^2$）

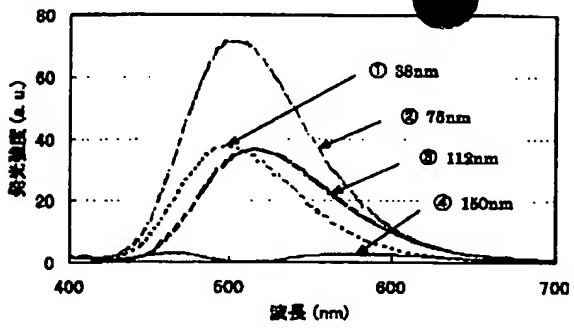
[Drawing 1]



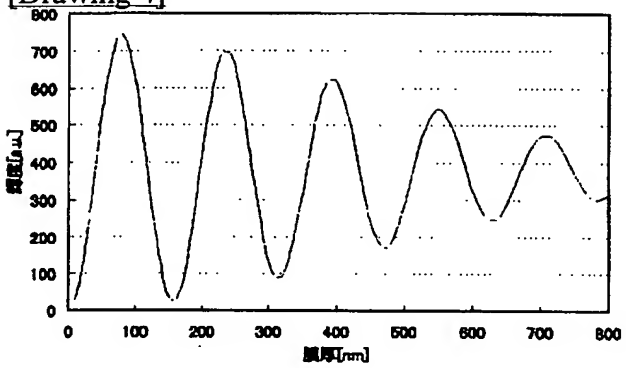
[Drawing 2]



[Drawing 3]



[Drawing 4]



[Drawing 6]

(a)

$$\delta r = \arctan\left(\frac{2nk_r}{n^2 - n_r^2 - k_r^2}\right) + \pi \qquad (\text{ただし、} n^2 \leqq n_r^2 + k_r^2)$$

(b)

$$R = \frac{(n - n_r)^2 + k_r^2}{(n + n_r)^2 + k_r^2}$$

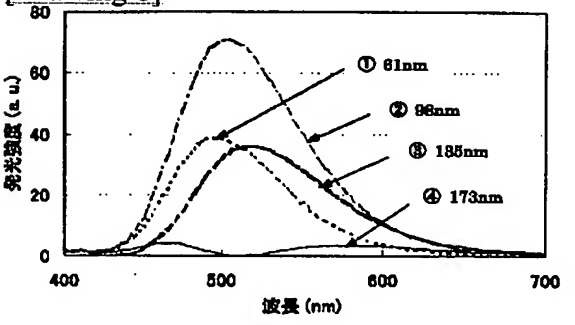
(c)

$$D(\lambda) = \frac{1 + R}{2} + \sqrt{R} \cos\delta$$

(d)

$$I(\lambda) = P(\lambda)\, D(\lambda)$$

[Drawing 8]



[Drawing 9]

各種金属の光学定数と反射光の位相変化および
(金属と接する有機材料の屈折率n＝1．7とした)

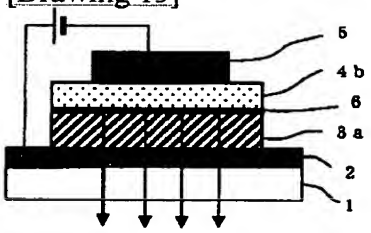
金属元素	光学定数		位相変化		反射率
	nr	kr	δr(rad)	δr/π	R
Mg	0.57	6.14	2.61	0.829	0.910
Ca	0.27	6.08	2.73	0.868	0.973
Sr	0.63	3.15	2.18	0.693	0.721
Ba	0.89	1.71	1.71	0.545	0.372
Mn	2.48	1.26	2.41	0.767	0.113
Ni	1.79	1.66	2.11	0.671	0.222
Pd	1.92	1.81	2.08	0.663	0.119
Al	0.93	6.33	2.63	0.836	0.865
Cu	0.756	2.462	1.99	0.634	0.575
Au	0.331	2.324	1.89	0.602	0.764
Ag	0.055	3.32	2.20	0.699	0.973

[Drawing 10]

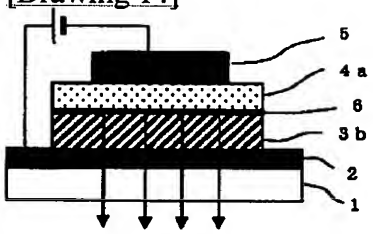
光学定数の異なる各種金属を陰極とした場合の
電子輸送層の最適膜厚（λ=510nm、n=1.7）

金属元素	最適膜厚(nm)		
	N=1	N=2	N=3
Mg	88	238	388
Ca	85	235	385
Sr	98	248	398
Ba	109	259	409
Mn	92	242	392
Ni	100	250	400
Pd	100	250	400
Al	87	237	387
Cu	102	252	402
Au	105	255	405
Ag	98	248	398
δr=πの場合	75	225	375

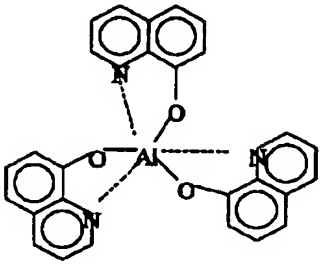
[Drawing 13]



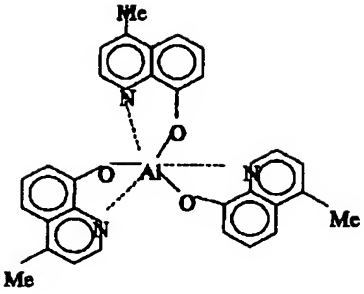
[Drawing 14]



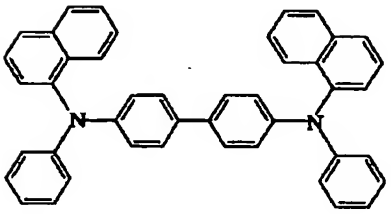
[Drawing 5]



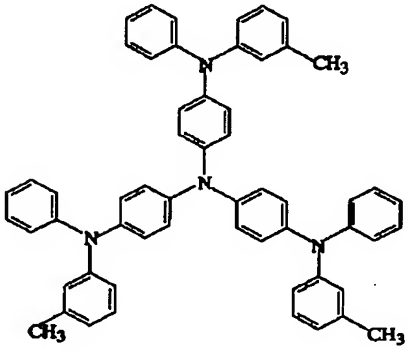
Aluminium 8-hydroxyquinolinate(Alq3)



Tris(4-Methyl-8-quinolinolato)Aluminium(Almq3)



Alpha-NPD



m-MTDATA

[Translation done.]

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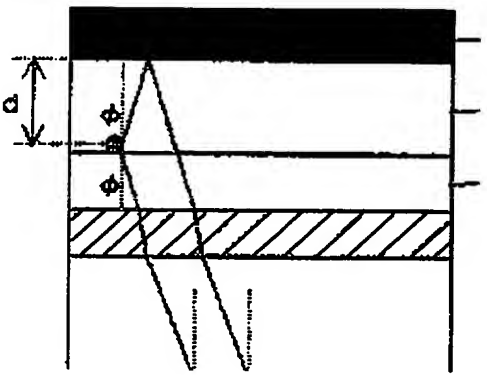
(54)【発明の名称】　有機エレクトロルミネッセンス素子

(57)【要約】
【課題】　発光効率（光の取り出し効率）が高く、高輝度で低消費電力の有機エレクトロルミネッセンス（ＥＬ）素子を提供すること。
【解決手段】　有機ＥＬ素子内で発光した光は、素子の前方に直接向かう光①と陰極１５で反射してから素子の前方に向かう光②の２つの経路がある。これらの光は、光路差があるので互いに干渉する。発光層から出て素子の前方に直接向かう光と陰極で反射した光の位相差δは、基板法線方向についてδ＝π＋４πＬ／λで求めら



1

【特許請求の範囲】

【請求項１】　透明導極からなる陽極と、
前記陽極上に少なくとも正孔輸送層と電子輸送層の２層を有して成膜された有機多層膜と、
前記有機多層膜層上に金属からなる鏡面反射膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送層の光学膜厚ｎｄは、
ｎｄ＝（２Ｎ－１）λ／４
（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことを特徴とする有機エレクトロルミネッセンス素子。

【請求項２】　透明導極からなる陽極と、
前記陽極上に正孔輸送層、電子輸送性発光層の順で２層を積層して成膜された有機多層膜と、
前記有機多層膜層上に金属からなる鏡面反射膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送性発光層の光学膜厚ｎｄは、
ｎｄ＝（２Ｎ－１）λ／４
（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことを特徴とする有機エレクトロルミネッセンス素子。

【請求項３】　透明導極からなる陽極と、
前記陽極上に正孔注入層、正孔輸送層、電子輸送性発光層の順で３層を積層して成膜された有機多層膜と、
前記有機多層膜層上に金属からなる鏡面反射膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送性発光層の光学膜厚ｎｄは、
ｎｄ＝（２Ｎ－１）λ／４
（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことを特徴とする有機エレクトロルミネッセンス素子。

【請求項４】　前記電子輸送性発光層は、前記正孔輸送層との界面付近に微量の蛍光性材料がドーピングされていることを特徴とする請求項２または請求項３記載の有機エレクトロルミネッセンス素子。

【請求項５】　透明導極からなる陽極と、
前記陽極上に正孔輸送層、膜厚が３０ｎｍ以下の発光層、電子輸送層の順で３層を積層して成膜された有機多層膜と、
前記有機多層膜層上に金属からなる鏡面反射膜で作製され

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前記陽極上に正孔輸送性発光層、電子輸
を積層して成膜された有機多層膜と、
前記有機多層膜層上に金属からなる鏡面反
た陰極と、を備え、
前記有機多層膜の電子輸送層の光学膜厚
ｎｄ＝（２Ｎ－１）λ／４
（ｎは屈折率、ｄは膜厚、λは発光の中
の整数）なる関係を満たすことを特徴と
トロルミネッセンス素子。

【請求項８】　前記陰極は、反射率が５
膜であることを特徴とする請求項１、請
３、請求項４、請求項５、請求項６、請
ずれか１に記載の有機エレクトロルミネ

【請求項９】　前記正の整数Ｎは、１で
とする請求項１、請求項２、請求項３、
項５、請求項６、請求項７、請求項８の
に記載の有機エレクトロルミネッセンス

【請求項１０】　前記電子輸送層または
発光層の光学膜厚ｎｄは、前記発光の中
以内の誤差範囲内であることを特徴とす
求項２、請求項３、請求項４、請求項５、
求項７、請求項８、請求項９のうちいず
有機エレクトロルミネッセンス素子。

【請求項１１】　透明導極からなる陽極、
前記陽極上に少なくとも正孔輸送層と電
を有して成膜された有機多層膜と、
前記有機多層膜層上に複素屈折率ｎ＊＝ｎ
する金属膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送層の光学膜厚
ｎｄ＝（λ／４）（２Ｎ－δｒ／π）
δｒ＝ａｒｃｔａｎ（２ｎｋ／（ｎ²－
）²））＋π
（ｎ²≦ｎ²＋Ｋ²であり、ｎは屈折率、
は発光の中心波長、Ｎは正の整数）なる
とを特徴とする有機エレクトロルミネッ

【請求項１２】　透明導極からなる陽極、
前記陽極上に正孔輸送層、電子輸送性発
を積層して成膜された有機多層膜と、
前記有機多層膜層上に複素屈折率ｎ＊＝ｎ
する金属膜で作製された陰極と、を備え、

前記有機多層膜層上に複素屈折率n~ ＝ｎｒ－ｉｋｒを有する金属膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送性発光層の光学膜厚ｎｄは、
ｎｄ＝（λ／４）（２Ｎ－δｒ／π）
δｒ＝ａｒｃｔａｎ（２ｎｋ,／（ｎ²－（ｎ,）²－（Ｋ,）²））＋π
（ｎ²≦ｎ,²＋Ｋ,²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことを特徴とする有機エレクトロルミネッセンス素子。
【請求項１４】　前記電子輸送性発光層は、前記正孔輸送層との界面付近に微量の蛍光性材料がドーピングされていることを特徴とする請求項１２または請求項１３記載の有機エレクトロルミネッセンス素子。
【請求項１５】　透明電極からなる陽極と、
前記陽極上に正孔輸送層、膜厚が３０ｎｍ以下の発光層、電子輸送層の順で３層を積層して成膜された有機多層膜と、
前記有機多層膜層上に複素屈折率n~ ＝ｎｒ－ｉｋｒを有する金属膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送層の光学膜厚ｎｄは、
ｎｄ＝（λ／４）（２Ｎ－δｒ／π）
δｒ＝ａｒｃｔａｎ（２ｎｋ,／（ｎ²－（ｎ,）²－（Ｋ,）²））＋π
（ｎ²≦ｎ,²＋Ｋ,²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことを特徴とする有機エレクトロルミネッセンス素子。
【請求項１６】　前記発光層は、微量の蛍光性材料がドーピングされていることを特徴とする請求項１５記載の有機エレクトロルミネッセンス素子。
【請求項１７】　透明電極からなる陽極と、
前記陽極上に正孔輸送性発光層、電子輸送層の順で２層を積層して成膜された有機多層膜と、
前記有機多層膜層上に複素屈折率n~ ＝ｎｒ－ｉｋｒを有する金属膜で作製された陰極と、を備え、
前記有機多層膜の電子輸送層の光学膜厚ｎｄは、
ｎｄ＝（λ／４）（２Ｎ－δｒ／π）
δｒ＝ａｒｃｔａｎ（２ｎｋ,／（ｎ²－（ｎ,）²－（Ｋ,）²））＋π
（ｎ²≦ｎ,²＋Ｋ,²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすセンス素子。
【請求項２０】　前記電子輸送層または発光層の光学膜厚ｎｄは、前記発光の中以内の誤差範囲内であることを特徴とす請求項１２、請求項１３、請求項１４、請求項１６、請求項１７、請求項１８、請いずれか１に記載の有機エレクトロルミ子。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、多面型の表示装置、光源としても利用可能である発光効率が高い有機エレクトロル子（以下、有機ＥＬ素子とする）に関す
【０００２】
【従来の技術】近年、インターネットに技術の進歩に伴って、ノート型パーソナタ、携帯端末、あるいは携帯電話などの普及してきている。これらの情報機器報を瞬時に処理し、表示することのでき能な平面型の表示装置が求められている。装置の代表的なものとしては液晶表示装表示装置は、低電圧駆動、低消費電圧で特を生かして、ノート型パーソナルコンピ話用の表示装置を初めとして、多くの電れている。ところが、液晶素子そのものにあるにも関わらず、自発光型ではないのでのカラー表示を行うためにはバックライこのバックライトの駆動に大きな電力をた、応答速度が遅いために、満足できるが難しく、視野角が狭いものである。一子は低電圧の直流駆動が可能であり、応性、高速応答性という表示素子として優る自発光型の表示素子として期待されて層型の素子構成で低電圧直流駆動、高発発光が報告されて以来、実用化に向けてされている（特公昭６４－７６３５号、３０７号、Ａｐｐｌ．Ｐｈｙｓ．Ｌｅｔ１３（１９８７）参照）。
【０００３】有機ＥＬ素子の基本的な技

な透明電極が最も多く用いられる。陰極には、仕事関数の小さな金属やその合金が用いられる。

【０００４】アルカリ金属、アルカリ土類金属および第３族金属があるが、安価で比較的に化学的安定性のよい材料であるＡｌやＭｇおよびその合金が最もよく用いられている。発光効率の向上のためには、陰極からの電子と陽極からの正孔の両キャリアを効率よく発光層に注入、輸送し、かつ注入された両キャリアのできるだけ多くを再結合させることが重要であるとされている。そのため、積層型の素子においては、キャリアの注入、輸送および発光という異なった機能を違う材料で分担させることによって、それぞれの材料を最適化して高い発光効率を実現できる可能性があることがわかり、活発に研究がなされるようになった。また、積層型の素子では、キャリアの再結合位置を電極から離れた位置に集約させるので、生成された励起子が電極の界面部分に移動して消失することを防いでいる。このような励起子の消失の影響は、電極から発光位置までの距離が約３０ｎｍ以下にならない方がよい。

【０００５】これまでに提案されている有機ＥＬ素子の構造には、有機多層膜の数によって主に２層型と３層型、およびこれらを基本とした改良型がある。２層型の素子は、発光層が電子輸送性または正孔輸送性を併せ持つものであって、正孔輸送層／電子輸送性発光層からなるもの（図１３を参照）と正孔輸送性発光層／電子輸送層からなるもの（図１４を参照）の２種類がある。正孔輸送層３ａ／電子輸送性発光層４ｂからなる２層型の素子は、ガラス基板１上の陽極２と電子輸送性をもった発光層である電子輸送層４ａとの間に電子輸送性のほとんどない正孔輸送層３ａを設けることで、効率よく正孔を注入、輸送すると共に陰極５から注入された電子を正孔輸送層３ａと発光層の界面でブロックして、電子と正孔との結合効率を向上させることを目的とする。この場合、電子と正孔の再結合は正孔輸送層発光層３ｂ／電子輸送性発光層４ｂの界面付近の発光層（発光位置）６でのみ発生し、その位置で最大の発光強度を示す。

【０００６】正孔輸送性発光層／電子輸送層からなる２層型の素子は、陰極と正孔輸送性をもった発光層との間に正孔をブロックするための電子輸送層を設けることで、電子と正孔との結合効率を向上させることを狙った

まで薄くしても発光効率は低下しないこ
る。これは、発光が５ｎｍの厚さの発光
いることを示している。このように多層
子の発光は、２層型か３層型かによらず
正孔が再結合する界面のごく近傍でのみ
光効率の改善は、現在でも有機ＥＬ素子
であり、これまでに多くの材料、構成が
る。

【０００７】ところで、特開平４－１３
には、陽極／正孔輸送性発光層／電子輸
成において、電子輸送層の厚さを３０～
高輝度を得る電界発光素子が開示されて
許第３０６５７０４号および特許第３０
は、陰極での反射光の干渉効果を利用す
ている。特許第２８４６５７１号公報に
波長における発光強度を増強するように、
極）と有機多層膜との合計光学膜厚と屈
有機エレクトロルミネッセンス素子が開
これは、発光層の位置から陰極までの光
するものではなく、また、陽極（透明電
界面での反射光と陰極での反射光との干
るので、透明電極と基板との界面での反
るために、透明電極には屈折率が１．８
透明電極を使用することが記載されてい
９７８８３号には、発光層の両面に形成
で微小共振器を形成して、反射鏡間の光
で多色表示をする多色発光素子とその基
いる。

【０００８】Ｊｐｎ．Ｊ．Ａｐｐｌ．Ｐ
１．３８（１９９９）ｐｐ．２７９９－
ｖａｌｕａｔｉｏｎ ｏｆ Ｔｒｕｅ
ｕｍｉｎｏｕｓ Ｅｆｆｉｃｉｅｎｃｙ
ｘｐｅｒｉｍｅｎｔａｌ Ｌｕｍｉｎａ
ｕｅｓ」（Ｔ．Ｔｓｕｔｓｕｉ ａｎ
ｍａｍａｔｏ）には、透明電極（ＩＴＯ
送層（ＴＰＤ）／電子輸送性発光層（Ａ
（ＭｇＡｇ）の構成の有機ＥＬ素子にお
性発光層（Ａｌｑ）の膜厚を変化させて
た発光スペクトルの変化、輝度の視角依
取り出し効率を正しく評価する試みが報

率の高い発光材料を用いても発光層から放射される光を有効に外部に取り出していないこと．すなわち光の取り出し効率が低いことに起因して、発光効率を高くできないという問題がある。これは、主に光取り出し側の基板面への入射角が臨界角を超えると全反射されるため、基板から外部に光を取り出すことができないことに起因している。例えば．通常のガラス基板では約２５％の取り出し効率になると考えられている。したがって．有機ＥＬ素子の発光効率向上のためには、発光層からの光を有効に素子外部に取り出すことのできる素子構成にすることが望まれている。

【００１０】従来から発光効率（発光の取り出し効率）を高める方法の一つとして．陰極からの反射光を有効に利用することが考えられる。すなわち．可視光領域で高い反射率を有する金属材料を陰極材料として用いれば、発光層から放射された光を素子前方（陽極側）に反射して有効に取り出すことができるが、発光層から出て素子の前方に直接向かう光と陰極で反射した光は互いに干渉しあうことが考えられ、この干渉効果についての正確かつ詳細な検討はなされていないのが現状である。また、上述の特開平４－１３７４８５号公報には、発光層と陰極との距離が発光強度を向上させるための重要な因子であることを示しているが．この時点では発光強度が電子輸送層の厚さに依存する理由については十分に解明されていないとしている。また．発光波長と膜厚との関係についての記述はみられず．光の干渉効果についての検討はなされていない。

【００１１】また、特許第３０６５７０４号および特許第３０６５７０５号の従来技術では．ＥＬ層あるいは電子輸送層の膜厚を膜厚頻度減衰曲線特性の２番目に高い頻度の２次極大値を含む膜厚を有し．かつその振幅がその収束する収束輝度値を超える頻度を生ずる範囲内の膜厚に設定することが述べられているが．特許第３０６５７０４号に記載されている光の干渉効果としての光の強度を表す「数式３」は、陰極で反射する光のπラジアンの位相変化を考慮しないで導かれたものであり．フレネルの反射の法則に反することになる。すなわち．フレネルの反射の法則によれば．光学的に疎な物質（屈折率の小さい物質）から密な物質（屈折率の大きな物質）に光が入射するとき．反射光の位相はπラジアンだけ変化す

あって、反射光の位相は反射面でほぼπ
ると考えるのが一般的であるが、実際の
率を有するので．反射面での反射光の実
はπラジアンからずれてしまう。また．
て形成された半透過膜、あるいは吸収の
おいても同様に反射面での反射光の実質
πラジアンからずれている。したがって、
料を選択するにあたっては．反射面での
な位相変化を考慮する必要があったが．
ような検討はなされていないのが現状で
許第２８４６５７１号公報では、ＥＬ発
から素子外部に取り出されるので陽極に
高い透過率が要求され、陰極のように大
極材料で構成することはできないので．
期待することはできない。したがって．
示された構成は色純度を向上させるため
が．大きな発光効率（光の取り出し効率
を期待することはできない。同様に特許
３号も発光層の位置から陰極までの光学
るものではない。さらに．光の干渉効果
な説明もなされていない。

【００１３】そこで、本発明の目的は．
取り出し効率）が高く、高輝度で低消費
素子を提供することである。

【００１４】

【課題を解決するための手段】請求項１
は．透明電極からなる陽極と、前記陽極
正孔輸送層と電子輸送層の２層を有して
多層膜と、前記有機多層膜層上に金属から
で作製された陰極と、を備え、前記有機
送層の光学膜厚ｎｄは、ｎｄ＝（２Ｎ－
（ｎは屈折率．ｄは膜厚．λは発光の中
の整数）なる関係を満たすことにより．
する。請求項２記載の発明では、透明電
と．前記陽極上に正孔輸送層、電子輸送
２層を積層して成膜された有機多層膜と、
層上に金属からなる鏡面反射膜で作製さ
備え．前記有機多層膜の電子輸送性発光
ｄは．ｎｄ＝（２Ｎ－１）λ／４、（ｎ
膜厚．λは発光の中心波長．Ｎは正の整

記電子輸送性発光層は、前記正孔輸送層との界面付近に微量の蛍光性材料がドーピングされていることにより、前記目的を達成する。

【００１５】請求項５記載の発明では、透明電極からなる陽極と、前記陽極上に正孔輸送層、膜厚が３０ｎｍ以下の発光層、電子輸送層の順で３層を積層して成膜された有機多層膜と、前記有機多層膜層上に金属からなる鏡面反射膜で作製された陰極と、を備え、前記有機多層膜の電子輸送層の光学膜厚ｎｄは、ｎｄ＝（２Ｎ－１）λ／４、（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことにより、前記目的を達成する。請求項６記載の発明では、請求項５記載の発明において、前記発光層は、微量の蛍光性材料がドーピングされていることにより、前記目的を達成する。

【００１６】請求項７記載の発明では、透明電極からなる陽極と、前記陽極上に正孔輸送性発光層、電子輸送層の順で２層を積層して成膜された有機多層膜と、前記有機多層膜上に金属からなる鏡面反射膜で作製された陰極と、を備え、前記有機多層膜の電子輸送層の光学膜厚ｎｄは、ｎｄ＝（２Ｎ－１）λ／４、（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことにより、前記目的を達成する。請求項８記載の発明では、請求項１、請求項２、請求項３、請求項４、請求項５、請求項６、請求項７のうちいずれか１に記載の発明において、前記陰極は、反射率が５０％以上の金属膜であることにより、前記目的を達成する。請求項９記載の発明では、請求項１、請求項２、請求項３、請求項４、請求項５、請求項６、請求項７、請求項８のうちいずれか１に記載の発明において、前記正の整数Ｎは、１であることにより、前記目的を達成する。請求項１０記載の発明では、請求項１、請求項２、請求項３、請求項４、請求項５、請求項６、請求項７、請求項８、請求項９のうちいずれか１に記載の発明において、前記電子輸送層または前記電子輸送性発光層の光学膜厚ｎｄは、前記発光の中心波長±λ／８以内の誤差範囲内であることにより、前記目的を達成する。

【００１７】請求項１１記載の発明では、透明電極からなる陽極と、前記陽極上に少なくとも正孔輸送層と電子輸送層の２層を有して成膜された有機多層膜と、前記有機多層膜層上に複素屈折率ｎ˜＝ｎｒ－ｉｋｒを有する金

膜で作製された陰極と、を備え、前記有機多層膜の電子輸送性発光層の光学膜厚ｎｄは、ｎｄ＝（Ｎ－δｒ／π）、δｒ＝ａｒｃｔａｎ（２ｎｋ／（ｎ²－（ｎ₀）²－（Ｋ₀）²））＋π、（ｎ²≦ｎ₀²＋Ｋ₀²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことにより、前記目的を達成する。請求項１３記載の発明では、前記陽極と、前記陽極上に正孔注入層、正孔輸送性発光層の順で３層を積層して成膜された有機多層膜と、前記有機多層膜層上に複素屈折率ｎ˜ｒを有する金属膜で作製された陰極と、を備え、前記有機多層膜の電子輸送性発光層の光学膜厚ｎｄは、ｎｄ＝（λ／４）（２Ｎ－δｒ／π）、δｒ＝ａｒｃｔａｎ（２ｎｋ₀／（ｎ²－（ｎ₀）²－（Ｋ₀）²））＋π、（ｎ²≦ｎ₀²＋Ｋ₀²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことにより、前記目的を達成する。請求項１４記載の発明では、請求項１２または請求項１３記載の発明において、前記電子輸送性発光層は、前記正孔輸送層との界面付近に微量の蛍光性材料がドーピングされていることにより、前記目的を達成する。

【００１８】請求項１５記載の発明では、透明電極からなる陽極と、前記陽極上に正孔輸送層、膜厚が３０ｎｍ以下の発光層、電子輸送層の順で３層を積層して成膜された有機多層膜と、前記有機多層膜層上に複素屈折率ｎ˜＝ｎｒ－ｉｋｒを有する金属膜で作製された陰極と、を備え、前記有機多層膜の電子輸送層の光学膜厚ｎｄは、ｎｄ＝（λ／４）（２Ｎ－δｒ／π）、δｒ＝ａｒｃｔａｎ（２ｎｋ₀／（ｎ²－（ｎ₀）²－（Ｋ₀）²））＋π、（ｎ²≦ｎ₀²＋Ｋ₀²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすことにより、前記目的を達成する。請求項１５記載の発明では、請求項１２または請求項１３記載の発明において、前記電子輸送性発光層は、前記正孔輸送層との界面付近に微量の蛍光性材料がドーピングされていることにより、前記目的を達成する。

【００１９】請求項１７記載の発明では、透明電極からなる陽極と、前記陽極上に正孔輸送性発光層、電子輸送層の順で２層を積層して成膜された有機多層膜と、前記有機多層膜層上に複素屈折率ｎ˜＝ｎｒ－ｉｋｒを有する金属膜で作製された陰極と、を備え、前記有

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では．請求項１１、請求項１２、請求項１３、請求項１４．請求項１５．請求項１６、請求項１７、請求項１８のうちいずれか１に記載の発明において、前記正の整数Nは．１であることにより．前記目的を達成する。請求項２０記載の発明では、請求項１１．請求項１２．請求項１３、請求項１４、請求項１５、請求項１６．請求項１７．請求項１８、請求項１９のうちいずれか１に記載の発明において．前記電子輸送層または前記電子輸送性発光層の光学膜厚ｎｄは．前記発光の中心波長±λ／８以内の誤差範囲内であることにより．前記目的を達成する。

【００２０】

【発明の実施の形態】以下．本発明の好適な実施の形態について図１ないし図１２を参照して詳細に説明する。まず．第１の実施形態の有機ＥＬ素子について説明する。本実施の形態の有機ＥＬ素子は．陰極が金属からなる鏡面反射膜であり、発光層から出て素子の前方に直接向かう光と陰極で反射した光とが干渉効果によって強め合うように、発光位置から陰極までの光学的距離を設定されている。ここで、陰極が鏡面反射膜であるとは、有機層との界面で反射光の位相が入射光に対して実質的にπラジアンだけ変化することを意味するものであり、金属材料に限られるわけではないが、反射率が高く．電子注入効率の高い金属材料が最も適している。また．発光材料特有の発光スペクトルの中心波長に対して最適な素子構成となるようにして．最も強い光を有効に素子外部に取り出すようにする。

【００２１】図１は、有機ＥＬ素子における光の干渉を示した図である。有機ＥＬ素子内で発光した光は．素子の前方に直接向かう光①と陰極１５で反射してから素子の前方に向かう光②の２つの経路がある。これらの光は．光路差があるので互いに干渉する。発光層から出て＊

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＊素子の前方に直接向かう光と陰極で反射δは．基板法線方向について以下の式（る。

$$\delta = \pi + 4\pi L/\lambda \quad (1)$$

【００２２】ここで、λは波長、Ｌは発面までの光学的距離である。光学的距離から反射面までに存在する有機材料（例素子においては電子輸送層）の光学膜厚る（ｎは屈折率．ｄは膜厚）。発光位置に存在する有機材料が複数の層からなる的距離Ｌは、各有機層の光学的距離（光なる。発光位置は、最大発光強度を示すａ／電子輸送性発光層１４ｂの界面．も（正孔輸送性）／電子輸送層の界面位置ができる。発光層内の発光強度分布が無であれば、電子輸送層の膜厚を若干調整の半分程度だけ厚めに）することで対応である。

【００２３】式（１）の右辺第一項のπ反射光の位相変化を意味する。直接光と果として素子外部に出てくる光の強度は、（２）で与えられるＤ（λ）に比例する。

$$D(\lambda) = 1 + \cos\delta \quad (2)$$

発光材料自体の発光スペクトルをＰ（λ子外部で観測される発光スペクトルＩ（（３）で表される。

$$I(\lambda) = P(\lambda)\,D(\lambda) \quad (3)$$

したがって、干渉の効果としての光の強のとき最大で．δ＝（２Ｎ＋１）πのと（ともにＮは正の整数である）。この条使って書き直すと以下のようになる。

強度が最大になる条件：$L = (2N-1)\lambda/4$ （４）

強度が最小になる条件：$L = N\lambda/2$ （５）

【００２４】本実施の形態の有機ＥＬ素子は、式（４）の条件を満たすように構成されている。また、式（４）で与えられる最大強度の得られる光学的距離Ｌからのずれ量が±λ／８の範囲内であれば、少なくとも収束強度値（膜厚が干渉長よりも厚い場合のように干渉効果が生じないときの光の強度値）よりも大きな強度が得られ

することができる。また．蛍光性材料をドーピングする場合には、ドーピングした位置での光学的距離Ｌは式（４）を満たすよる。干渉の次数を表す正の整数Ｎが１のと．有機膜（電子輸送層）の膜厚を薄く圧駆動に有効である。有機ＥＬ素子に用

【００２６】図２に示したフォトルミネッセンス・スペクトルＰ（λ）と式（１）．式（２）．式（３）とを用いて．屈折率ｎ＝１．７の有機膜について、発光位置から陰極までの距離（電子輸送層の膜厚）が、①３８ｎｍ．②７５ｎｍ．③１１２ｎｍ、④１５０ｎｍの場合について計算した発光スペクトルを図３に示す。膜厚が７５ｎｍで発光強度は最大．１５０ｎｍで最小、３８ｎｍ．１１２ｎｍではほぼ中間の値であることがわかる。また．膜厚を少しずつ変化させて計算したスペクトルをもとに、ＪＩＳ－Ｚ８７０１－１９８２にしたがってってＣＩＥ表色系を計算して求めた輝度値を図４に示す。膜厚が４００ｎｍ以下においては、輝度の最大と最小が明らかに逆転していることがわかる。

【００２７】次に、本実施の形態に係る有機ＥＬ素子の作製方法について説明するが、基本的には公知の方法を用いることができる。まず．ガラス基板上にＩＴＯなどの透明電極を真空蒸着あるいはスパッタリングなどにより１０～３００ｎｍ程度の膜厚で形成し、これを陽極とする。ＩＴＯ付のガラス基板として市販されているものが容易に入手可能である。ＩＴＯ上には正孔輸送層、発光層．電子輸送層等の有機材料を真空蒸着法、スピンコーティング法等によって所定の膜厚になるように順次形成する。２層型の素子においては、正孔輸送層あるいは電子輸送層が発光層を兼ねることになる。

【００２８】本実施の形態の有機ＥＬ素子において用いられる発光層．正孔輸送層．および電子輸送層を形成する材料は、図５に示したように例えば．正孔輸送性の材料としては、トリフェニルジアミン誘導体（ＴＰＤ）、トリフェニルアミン誘導体（ＮＳＤ）．α－ナフチルフェニルアミン（α－ＮＰＤ）、フタロシアニン類（ＣｕＰｃ、Ｈ２Ｐｃ）．スターバーストポリアミン類（ｍ－ＭＴＤＡＴＡ）などが用いられる。　電子輸送材料としては、アルミキノリノール錯体（Ａｌｑ３）、メチルアルミキノリノール錯体（４－Ｍｅｔｈｙｌ－８－ｈｙｄｒｏｘｙｑｕｉｎｏｌｉｎｅ：Ａｌｍｑ３）、ベリリウムーキノリン錯体（Ｂｅｑ２）などを用いることができ．これらの材料は同時に発光性材料としても使用される。オキサジアゾール誘導体（ＰＢＤ）は、優れた電子輸送材料としてよく知られている。ＰＢＤのような電子輸送性の良好な材料を電子輸送層として用いれば．発光

を抵抗加熱、電子ビーム等による蒸着法
金ターゲットを用いたスパッタリング法
０～３００ｎｍ程度の膜厚で形成される。
と低抵抗の膜を得るには．好ましくは１
膜厚にすることが望ましい。陰極に用い
としては、仕事関数が小さい金属、例え
ウム）、Ｎａ（ナトリウム）、Ｍｇ（マ
Ｃａ（カルシウム）、Ｓｒ（ストロンチ
（アルミニウム）、Ａｇ（銀）、Ｉｎ（
Ｓｎ（スズ）．Ｚｎ（亜鉛）、Ｚｒ（ジ
どの金属元素単体あるいはこれらの合金
さらに陰極上に電極保護膜としてＬｉＦ
合と同様の方法で形成してもよい。なお、
では．実質的にπだけ位相変化する鏡面
る金属膜からなる陰極を用いている限り
の積層構成の違いによらず．発光層の位
の光学的距離を本発明に基づいて設定す
発光効率の改善をすることができる。さ
素子に限らず．鏡面反射を利用する類似
おいて、本実施の形態の基本的な考え方
も可能である。

【００３０】以下、第１の実施形態の変
２について説明するが、本実施の形態に
子はこれらの実施形態における材料．素
定されるものではない。

（１）変形例１

板厚が１．１ｍｍのＩＴＯ付ガラス基板
的なレジストを用いたフォトリソグラフ
２ｍｍ幅の陽極パターンを形成する。次
界面活性剤を用いて洗浄し．十分に純水
した後にイソプロピルアルコールの蒸気
さらに酸素プラズマ処理によって十分に
を取り除く。このようにして準備した基
置内にセットし．正孔輸送材料としてα
加熱によって真空蒸着して．膜厚が７０
層を形成する。蒸着条件は．真空度が２．
Ｐａ．蒸着レートが１ｎｍ／秒とし．さ
Ａｌｍｑ３を同様に蒸着して７５ｎｍの電
層とする。

【００３１】次に．ＩＴＯ電極パターン．

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離は．ｎｄ＝（２Ｎ－１）λ／４で与えられている関係式を満足する。なお、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数である。

【００３２】（２）変形例２

正孔注入層として、ｍ－ＭＴＤＡＴＡをＩＴＯ電極上に３０ｎｍの膜厚で形成し．つづいて正孔輸送層として、α－ＮＰＤを５０ｎｍの膜厚で形成し．さらにＡｌｍｑ₃からなる電子輸送性発光層を７５ｎｍの膜厚で形成する。その他の構成は、変形例１と同様にして有機ＥＬ素子を作製する。

【００３３】次に、第２の実施形態の有機ＥＬ素子について説明する。本実施形態の有機ＥＬ素子では．第１の実施形態と同様に陰極が金属反射膜であり、発光層から出て素子の前方に直接向かう光と陰極で反射した光とが干渉効果によって強め合うように、発光位置から陰極までの光学的距離を設定する。陰極が光反射能を有し、反射面での反射光の実質的な位相変化を考慮してなされたものであり、金属材料に限られるわけではないが．反射率が高く、電子注入効率の高い金属材料が最も適している。また、発光材料特有の発光スペクトルの中心波長に対して最適な素子構成となるようにして、最も強い光を有効に素子外部に取り出す。

【００３４】有機ＥＬ素子内で発光した光は、素子の前方に直接向かう光①と陰極で反射してから素子の前方に向かう光②の２つの経路がある（図１参照）。これらの光は光路差があるので互いに干渉する。発光層から出て素子の前方に直接向かう光と陰極で反射した光の位相差δは．反射面での反射光の位相変化をδｒと表して、基板法線方向について以下の式（６）で与えられる。

$$\delta = \delta r + 4\pi L/\lambda \qquad (6)$$

なお．λは波長．Ｌは発光位置から反射面までの光学的距離である。光学的距離Ｌは、発光位置から反射面までに存在する有機材料（例えば２層型の素子においては電子輸送層）の光学膜厚ｎｄで与えられる（ｎは屈折率、ｄは膜厚）。発光位置から反射面までに存在する有機材料が複数の層からなる場合には、光学的距離Ｌは各有機層の光学的距離（光学膜厚）の和となる。発光位置は、最大発光強度を示す正孔輸送層／発光層（電子輸送性）．の界面、もしくは発光層（正孔輸送性）／電子輸送層の界面位置で代表することができる。発光層内の発光強度

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数は．反射率測定やエリプソメトリ法な．
される（なお．金属元素の光学定数は．
善．裳華房、２０９ページや、「光学概
善．朝倉書店．５０ページ（Ａｍｅｒｉ
ｔｉｔｕｔｅ　ｏｆ　Ｐｈｙｓｉｃｓ
ｋ　（ＭｃＧｒａｗ－Ｈｉｌｌ，１９７
８参照）。直接光と反射光の干渉効果と
出てくる光の強度は、図６（ｃ）で与え
に比例する。

【００３６】発光材料自体の発光スペク
とすると、素子外部で観測される発光ス
（λ）は、図６（ｄ）で表される。した
効果としての光の強度は．δ＝２Ｎπの
＝（２Ｎ＋１）πのとき最小となる（と
数）。この条件は、式（１）を使って書
ようになる。本実施の形態の有機ＥＬ素
（ａ）の式の条件を満たすように素子を
た．図７（ａ）で与えられる最大強度の
距離Ｌからのずれ量が±λ／８の範囲内
くとも収束強度値（膜厚が干渉長よりも
に干渉効果が生じないときの光の強度値
強度が得られる。すなわち．本実施の形
図７（ａ）を完全に満足するように素子
少なくとも±λ／８の範囲内で満たして
た．発光強度が最大になる光学的距離お
範囲は波長によって異なるので、各種
スペクトルに応じて設定される。

【００３７】また、本実施の形態の有機
は．従来技術の２層型や３層型の素子．
光強度を示す界面位置がわかっている場
いて適用することができる。また、蛍光
にドーピングする場合には．ドーピング
に陰極までの光学的距離Ｌは、図７（ａ
ように設定される。干渉の次数を表す正
場合を採用すれば、有機膜（電子輸送層
できるので低電圧駆動に有効である。有
いられる有機材料の屈折率ｎは、１．６
ある。

【００３８】例として、Ａｇの蒸着膜の
０．０５５．ｋｒ＝３．３２について．

影響は生じない。

【００３９】発光材料特有の発光スペクトルの例として．分光蛍光光度計を用いて測定した．Ａｌｍｑ₃のフォトルミネッセンス・スペクトルＰ（λ）を第１の実施形態と同様に図２に示す。発光の中心波長は、λ＝５１０ｎｍにみられる。図２に示したフォトルミネッセンス・スペクトルＰ（λ）と図６（ｃ）．（ｄ）を用いて、屈折率ｎ＝１．７の有機膜について．発光位置から陰極までの距離（電子輸送層の膜厚）が．①６１ｎｍ．②９８ｎｍ、③１３５ｎｍ、④１７３ｎｍの場合について計算した発光スペクトルを図８に示す。膜厚が９８ｎｍ（Ｎ＝１に対応）で発光強度は最大となっており．材料本来の発光スペクトルが再現されている。膜厚が１７３ｎｍで発光強度は最小、６１ｎｍ、１３５ｎｍではほぼ中間の値であることがわかる。

【００４０】以下、第２の実施形態の有機ＥＬ素子の作製方法について説明する。なお、有機ＥＬ素子の作製方法は．基本的には公知の方法を用いることができる。まず．ガラス基板上にＩＴＯ等の透明電極を真空蒸着あるいはスパッタリング等により１０～３００ｎｍ程度の膜厚で形成し、これを陽極とする。あるいはＩＴＯ付のガラス基板として市販されているものが容易に入手可能である。ＩＴＯ上には正孔輸送層、発光層、電子輸送層等の有機材料を真空蒸着法．スピンコーティング法などによって所定の膜厚になるように順次形成する。２層型の素子においては．正孔輸送層あるいは電子輸送層が、発光層を兼ねることになる。

【００４１】本実施の形態の有機ＥＬ素子において用いられる発光層．正孔輸送層．および電子輸送層を形成する材料は、従来のものを用いることができる。図５に示したような例えば、正孔輸送性の材料としては．トリフェニルジアミン誘導体（ＴＰＤ）、トリフェニルアミン誘導体（ＮＳＤ）、α－ナフチルフェニルアミン（α－ＮＰＤ）、フタロシアニン類（ＣｕＰｃ、H_2Ｐｃ）．スターバーストポリアミン類（ｍ－ＭＴＤＡＴＡ）などが用いられる。電子輸送材料としては．アルミキノリノール錯体（Ａｌｑ₃）．メチルアルミキノリノール錯体（４－Ｍｅｔｈｙｌ－８－ｈｙｄｒｏｘｙｑｕｉｎｏｌｉｎｅ：Ａｌｍｑ３）、ベリリウムーキノリン錯体（Ｂｅｑ₂）などがあり．これらの材料は同時に発をホスト材料とし、正孔輸送層との界面m以内）に蛍光材料を数ｍｏｌ％～数１ドーピングすることができる。次に．陰を抵抗加熱、電子ビームなどによる蒸着台金ターゲットを用いたスパッタリング０～３００ｎｍ程度の膜厚で形成される。率と低抵抗の膜を得るには．好ましくはの膜厚にすることが望ましい。陰極に用料としては、仕事関数が小さい金属．例ａ．Ｍｇ、Ｃａ．Ｓｒ、Ｂａ、Ｔｉ．Ｍｇ．Ｉｎ、Ｓｎ．Ｚｎ、Ｚｒなどの金属はこれらの合金が用いられる。アルカリ膜との密着性をよくし、酸素や水分などけるために、Ａｇ、Ａｌなどとの合金とらに陰極上に電極保護膜としてＬｉＦ．極の場合と同様の方法で形成してもよい。

【００４３】各種金属元素の光学定数と位相変化および反射率を図９に示す。金機材料の屈折率は、ｎ＝１．７とする。すべて、δｒがπ／２～πの範囲内にあ属元素を陰極に用いて有機ＥＬ素子を形電子輸送層の最適な膜厚を図６（ａ）の次数が、Ｎ＝１．２、３の場合で計算しに示す。これら以外の金属やその他の合数．あるいは光学定数の波長分散は．エなどによって測定可能である。

【００４４】以下、第２の実施形態の変いて説明するが．第２の実施形態の変形料．素子構成だけに限定されるものでは

（１）変形例１

陰極を形成する金属材料としては、アル１）を使用する。板厚が１．１ｍｍのＩＴＯ板を用意し、一般的なレジストを用いたフィー法によって２ｍｍ幅の陰極パター次に．この基板を界面活性剤を用いて洗水で洗剤を洗い流した後にイソプロピル気中で乾燥させ．さらに酸素プラズマ処に表面洗浄の汚れを取り除く。このよう基板を真空蒸着装置内にセットし、正孔α－ＮＰＤを抵抗加熱によって真空蒸着

うな穴のあけられたメタルマスクを基板に密着させて真空蒸着装置内にセットした状態で、アルミニウム（Ａｌ）を真空蒸着して膜厚１６０ｎｍの金属膜を形成し陰極とし、２ｍｍ角の点灯領域を得る。Ａｌ陰極上に膜厚が３００ｎｍのＬｉＦを蒸着して保護膜を形成する。さらに、不活性ガス（Ａｒ）雰囲気中で、この素子の上に１ｍｍ厚のパイレックスガラスを重ね、紫外線硬化型の接着剤を用いてガラス周辺を封止して、有機ＥＬ素子を得る。

【００４６】（２）変形例２

正孔注入層として、ｍ－ＭＴＤＡＴＡをＩＴＯ電極上に３０ｎｍの膜厚で形成し、つづいて正孔輸送層として、α－ＮＰＤを５０ｎｍの膜厚で形成し、さらに変形例１と同様にＡｌｍｑ３からなる電子輸送性発光層を８７ｎｍの膜厚で形成する。その他の構成は、変形例１と同様にして有機ＥＬ素子を作製する。

【００４７】（３）変形例３

陰極を形成する金属材料として、膜厚が１５０ｎｍのＭｇＡｇ合金を使用した以外は、変形例２と同じ有機材料を用いて有機ＥＬ素子を構成する。陰極の製膜はＭｇとＡｇを用いた共蒸着によって行う。ＭｇＡｇ合金の光学定数は、素子を形成する場合と同じ条件でガラス基板上に製膜したサンプルを用いて、エリプソメトリ法によって測定した結果、ｎｒ＝０．３、ｋｒ＝５であった。この光学定数を使って、図１２の式から求めた反射面での反射光の位相変化は、δｒ＝２．５（ラジアン）となる。電子輸送層の膜厚は、図１１のような式からＮ＝１として求められる膜厚値９１ｎｍになるように製膜する。

【００４８】

【発明の効果】請求項１記載の発明では、有機多層膜の電子輸送層の光学膜厚ｎｄは、ｎｄ＝（２Ｎ－１）λ／４．（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすので、光の外部取り出し効率を高くすることができ、消費電力の低減を有効に図ることができる。請求項２記載の発明では、有機多層膜の電子輸送性発光層の光学膜厚ｎｄは、ｎｄ＝（２Ｎ－１）λ／４、（ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすので、光の外部取り出し効率を高くすることができ、消費電力の低減を

層の光学膜厚による干渉効果をさらに高める。

【００４９】請求項５記載の発明では、電子輸送層の光学膜厚ｎｄは、ｎｄ＝（２４．（ｎは屈折率、ｄは膜厚、λは発光は正の整数）なる関係を満たすので、光効率を高くすることができ、消費電力の現することができる。請求項６記載の発は、微量の蛍光性材料がドーピングされ光効率を高くでき、キャリアの再結合領光位置をドーピングによって制御でき、学膜厚による干渉効果をさらに高めること求項７記載の発明では、有機多層膜の電膜厚ｎｄは、ｎｄ＝（２Ｎ－１）λ／４、率、ｄは膜厚、λは発光の中心波長、Ｎる関係を満たすので、光の外部取り出しことができ、消費電力の低減を容易に実きる。

【００５０】請求項８記載の発明では、が５０％以上の金属膜であるので、干渉り出すことができる。請求項９記載の発数Ｎは、１であるので、すなわち１次のことになり、有機膜の膜厚を薄くでき、果があり、また、このときの電子輸送層子の陰極への移動による消光の影響があく、通常の蒸着法によって容易に制御する。請求項１０記載の発明では、電子輸輸送性発光層の光学膜厚ｎｄは、発光の８以内の誤差範囲内であるので、干渉効度の増強効果を確保し、収束強度値より得られ、実質的な膜厚の許容範囲を示す製造工程および製品の品質管理を容易とする。

【００５１】請求項１１記載の発明では、電子輸送層の光学膜厚ｎｄは、ｎｄ＝（－δｒ／π）．δｒ＝ａｒｃｔａｎ（２（ｎｒ）²－（Ｋｒ）²））＋π、（ｎ²≦ｎり．ｎは屈折率、ｄは膜厚、λは発光の正の整数）なる関係を満たすので、光の率を高くすることができ、消費電力の低

ａｎ（２ｎｋ,／（ｎ²－（ｎ,）²－（Ｋ,）²））＋π、（ｎ²≦ｎ,²＋Ｋ,²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすので、光の外部取り出し効率を高くすることができ、消費電力の低減を容易に実現することができる。請求項１４記載の発明では、電子輸送性発光層は、正孔輸送層との界面付近に微量の蛍光性材料がドーピングされているので、発光効率を高くでき、キャリアの再結合領域、すなわち発光位置をドーピングによって制御でき、電子輸送層の光学膜厚による干渉効果をさらに高めることができる。

【００５２】請求項１５記載の発明では、有機多層膜の電子輸送層の光学膜厚ｎｄは、ｎｄ＝（λ／４）（２Ｎ－δｒ／π）、δｒ＝ａｒｃｔａｎ（２ｎｋ,／（ｎ²－（ｎ,）²－（Ｋ,）²））＋π、（ｎ²≦ｎ,²＋Ｋ,²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすので、光の外部取り出し効率を高くすることができ、消費電力の低減を容易に実現することができる。請求項１６記載の発明では、発光層は、微量の蛍光性材料がドーピングされているので、発光効率を高くでき、キャリアの再結合領域、すなわち発光位置をドーピングによって制御でき、電子輸送層の光学膜厚による干渉効果をさらに高めることができる。請求項１７記載の発明では、有機多層膜の電子輸送層の光学膜厚ｎｄは、ｎｄ＝（λ／４）（２Ｎ－δｒ／π）、δｒ＝ａｒｃｔａｎ（２ｎｋ,／（ｎ²－（ｎ,）²－（Ｋ,）²））＋π、（ｎ²≦ｎ,²＋Ｋ,²であり、ｎは屈折率、ｄは膜厚、λは発光の中心波長、Ｎは正の整数）なる関係を満たすので、光の外部取り出し効率を高くすることができ、消費電力の低減を容易に実現することができる。

【００５３】請求項１８記載の発明では、陰極は、反射率が５０％以上の金属膜であるので、干渉効果を有効に取り出すことができる。請求項１９記載の発明では、正の整数Ｎは、１であるので、すなわち１次の干渉を利用することにより有機膜の膜厚を薄くでき、低電圧駆動に効果があり、また、このときの電子輸送層の膜厚は、励起子の陰極への移動による消光の影響があるほど薄くなく、通常の蒸着法によって容易に制御することができる。請求項２０記載の発明では、電子輸送層または電子

＊度の増強効果を確保し、収束強度値より得られ、実質的な膜厚の許容範囲を示す工程および製品の品質管理を容易とする

【図面の簡単な説明】

【図１】有機ＥＬ素子における光の干渉る。

【図２】Ａｌｍｑ₃のフォトルミネッセンルを示した図である。

【図３】第１の実施形態での電子輸送層場合の発光スペクトルの違いを示した図

【図４】電子輸送層の膜厚と輝度値の関ある。

【図５】電子輸送性材料と正孔輸送性材した図である。

【図６】位相変化δｒ、エネルギー反射度、発光スペクトルｉ（λ）を求める式る。

【図７】強度条件に応じた発光位置から学的距離を求める式を示した図である。

【図８】第２の実施形態での電子輸送層場合の発光スペクトルの違いを示した図

【図９】各種金属元素の光学定数と反射変化および反射率を示した図である。

【図１０】光学定数の異なる各種金属をの電子輸送層の最適膜厚を示した図であ

【図１１】有機ＥＬ素子の電子輸送層の条件（１）を示した図である。

【図１２】有機ＥＬ素子の電子輸送層の条件（２）を示した図である。

【図１３】電子輸送性発光層を有する２素子の層構成を示す概略断面図である。

【図１４】正孔輸送性発光層を有する２素子の層構成を示す概略断面図である。

【符号の説明】

１　ガラス基板

２　陽極（透明電極）

３ａ．１３ａ　正孔輸送層

３ｂ　正孔輸送性発光層

４ａ　電子輸送層

４ｂ．１４ｂ　電子輸送性発光層